WATERING THE BAKKEN

WATER QUANTITY

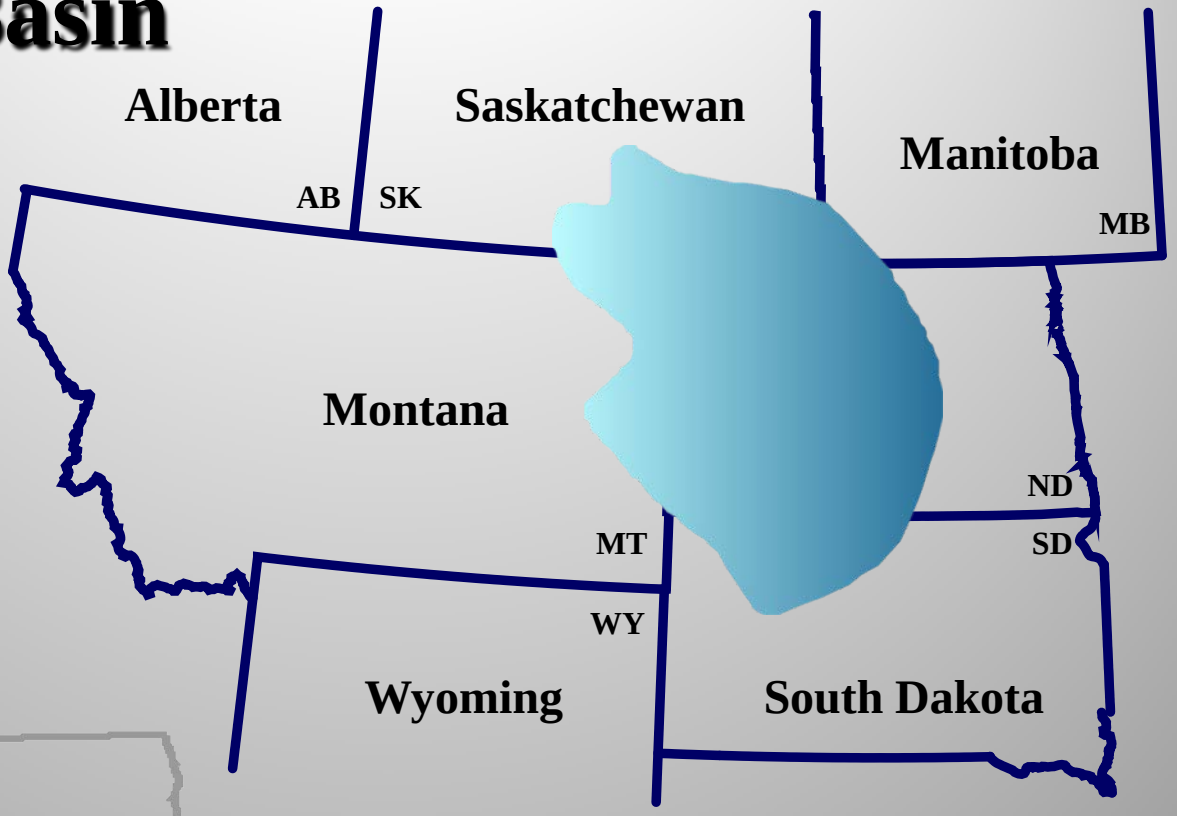
and

WATER QUALITY

CONCERNS

WESTERN NORTH DAKOTA MIDDLE BAKKEN OIL & GAS PLAY

Williston Basin



WILLISTON BASIN NORTH DAKOTA

Stratigraphic Column

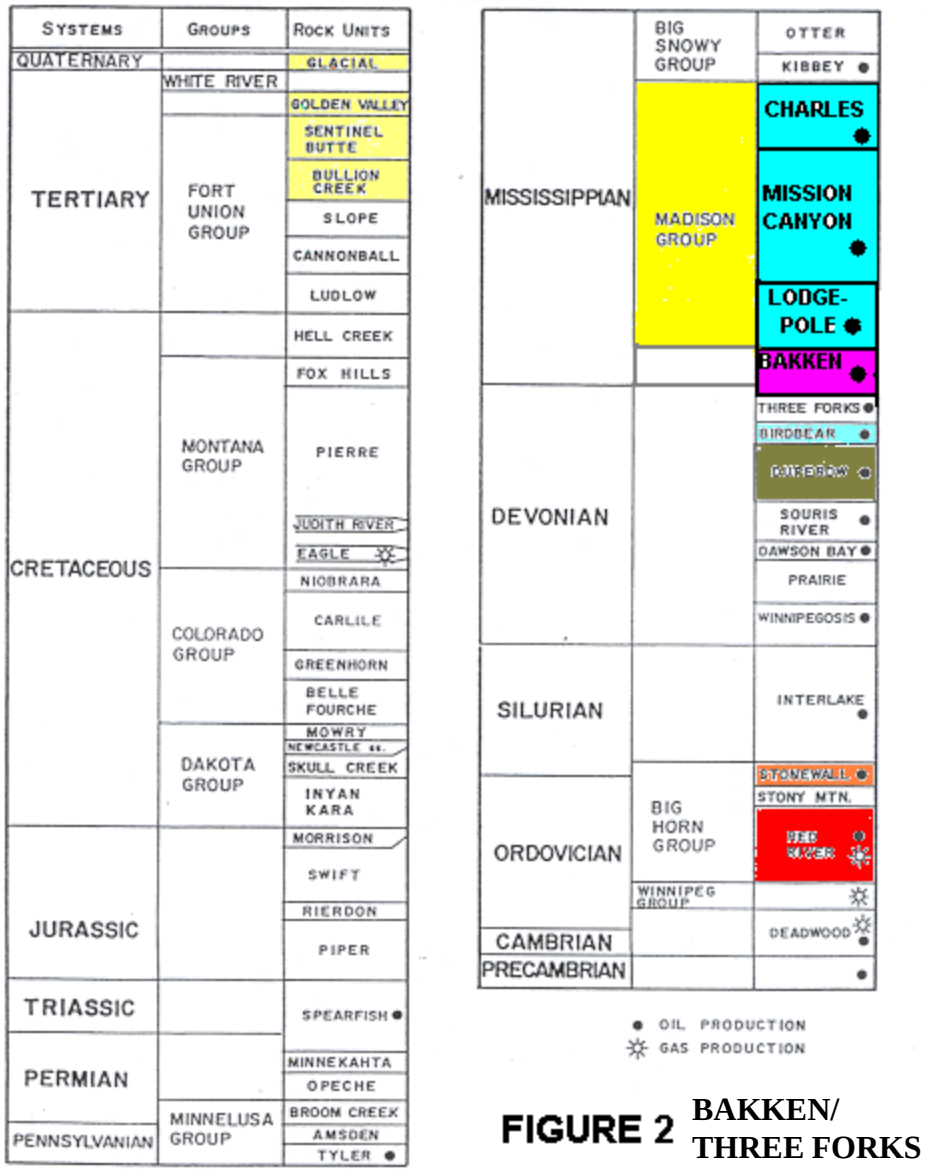


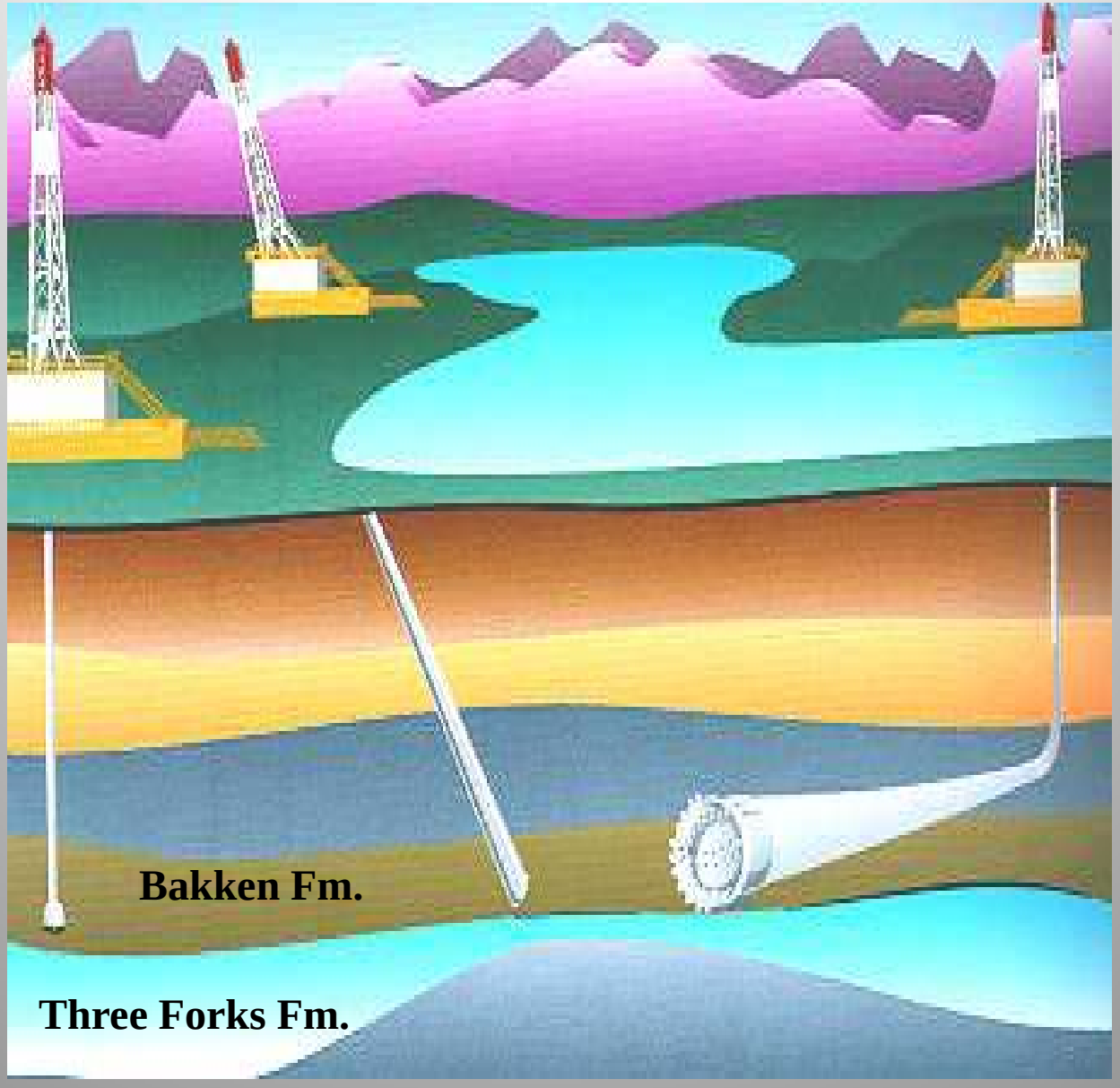
FIGURE 2 BAKKEN/ THREE FORKS

- Lodgepole
- Bakken
- Three Forks

Slant/Deviated

Horizontal Bakken/Three Forks

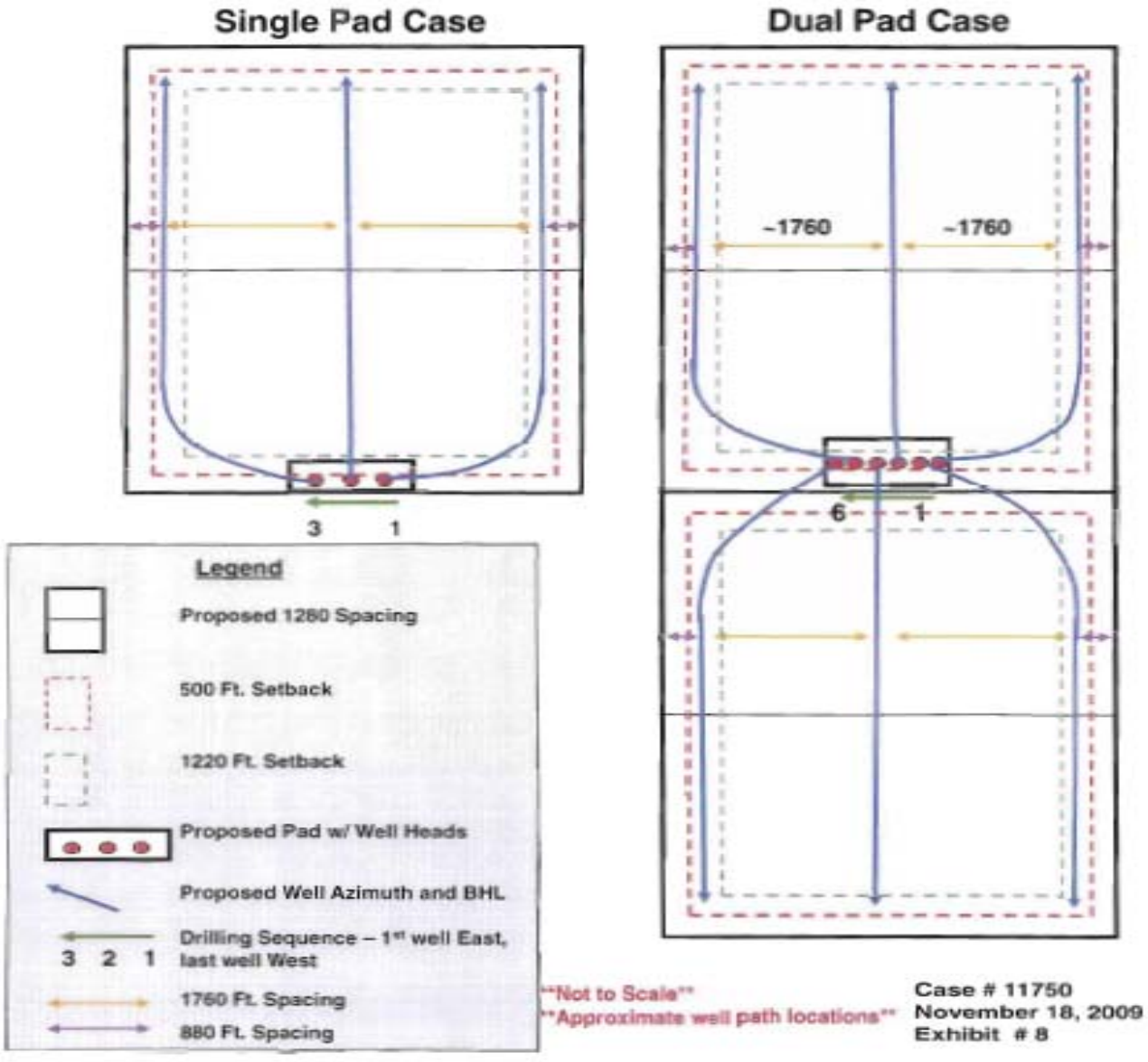
Conventional Vertical

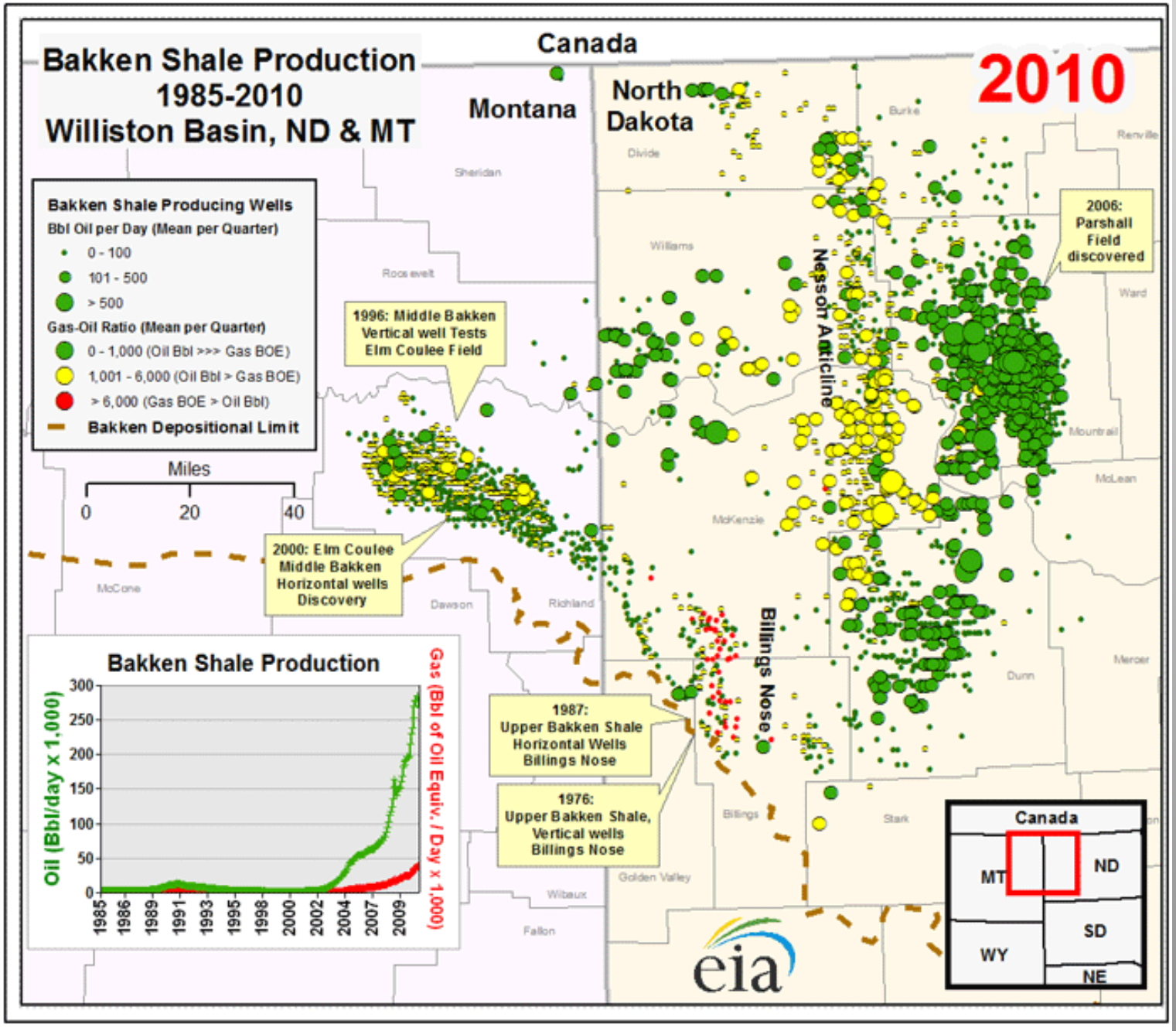


Vertical, Slant/Deviated & Horizontal Drilling

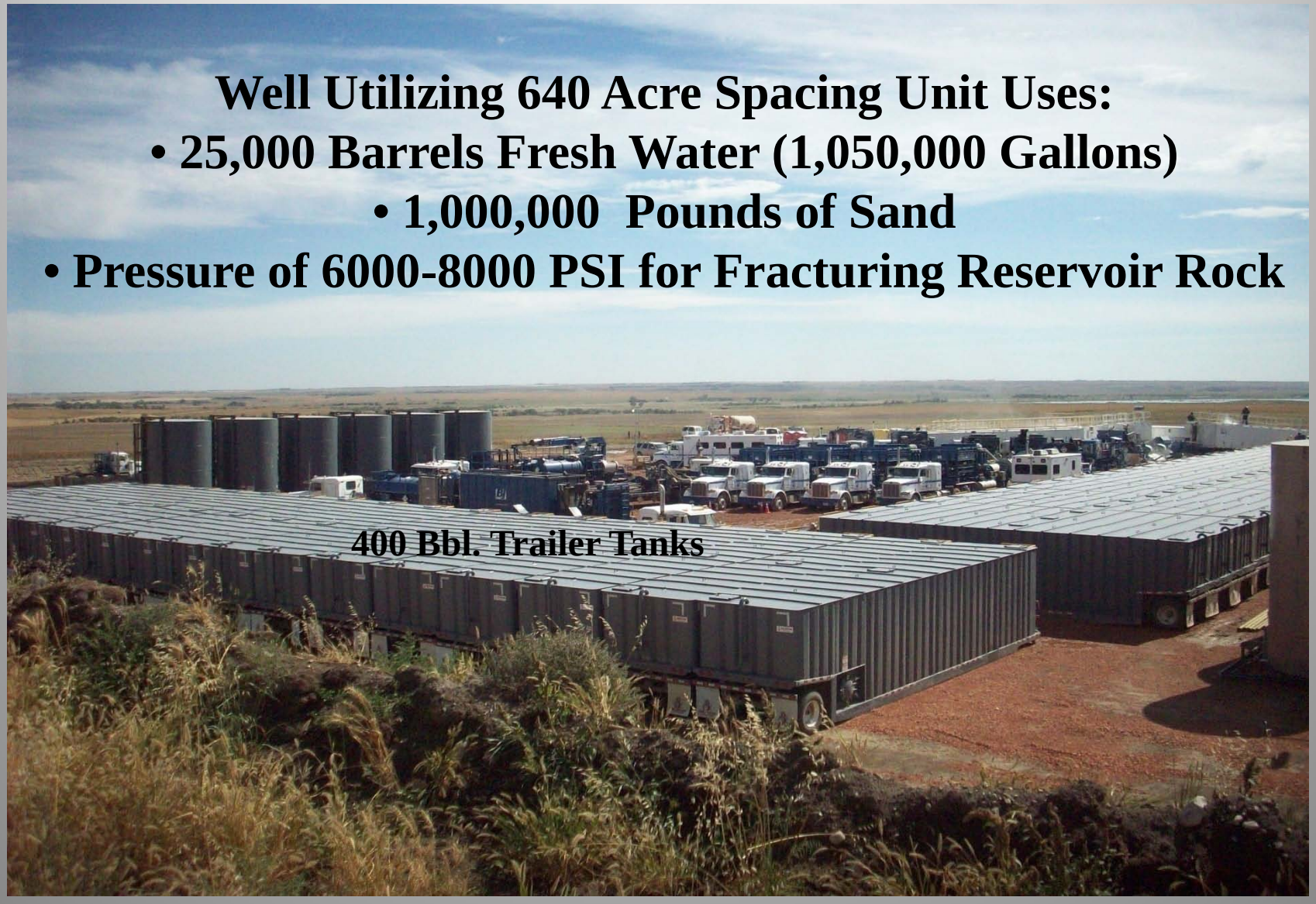
WELL PAD DESIGN

640 Acre & 1280 Acre Spacing




Bakken Shale Production
1985-2010
Williston Basin, ND & MT
Canada
Montana
North Dakota
2010
Bakken Shale Producing Wells
Bbl Oil per Day (Mean per Quarter)
0 - 100
101 - 500
> 500
Gas-Oil Ratio (Mean per Quarter)
0 - 1,000 (Oil Bbl >>> Gas BOE)
1,001 - 6,000 (Oil Bbl > Gas BOE)
> 6,000 (Gas BOE > Oil Bbl)
Bakken Depositional Limit
Miles
0
20
40
1996: Middle Bakken Vertical well Tests Elm Coulee Field
2000: Elm Coulee Middle Bakken Horizontal wells Discovery
2006: Parshall Field discovered
1987: Upper Bakken Shale Horizontal Wells Billings Nose
1976: Upper Bakken Shale, Vertical wells Billings Nose
Nesson Anticline
Billings Nose
Sheridan
Roosevelt
Divide
Burke
Renville
Williams
Ward
Mountrail
McLean
McKenzie
McCone
Dawson
Richland
Dunn
Mercer
Billings
Stark
Golden Valley
Wibaux
Fallon
Bakken Shale Production
Oil (Bbl/day x 1,000)
Gas (Bbl of Oil Equiv. / Day x 1,000)
300
250
200
150
100
50
0
1985
1986
1989
1991
1993
1995
1998
2000
2002
2004
2007
2009
Canada
MT
ND
SD
WY
NE
eia

FRAC JOB 400’X400’ WELL PAD



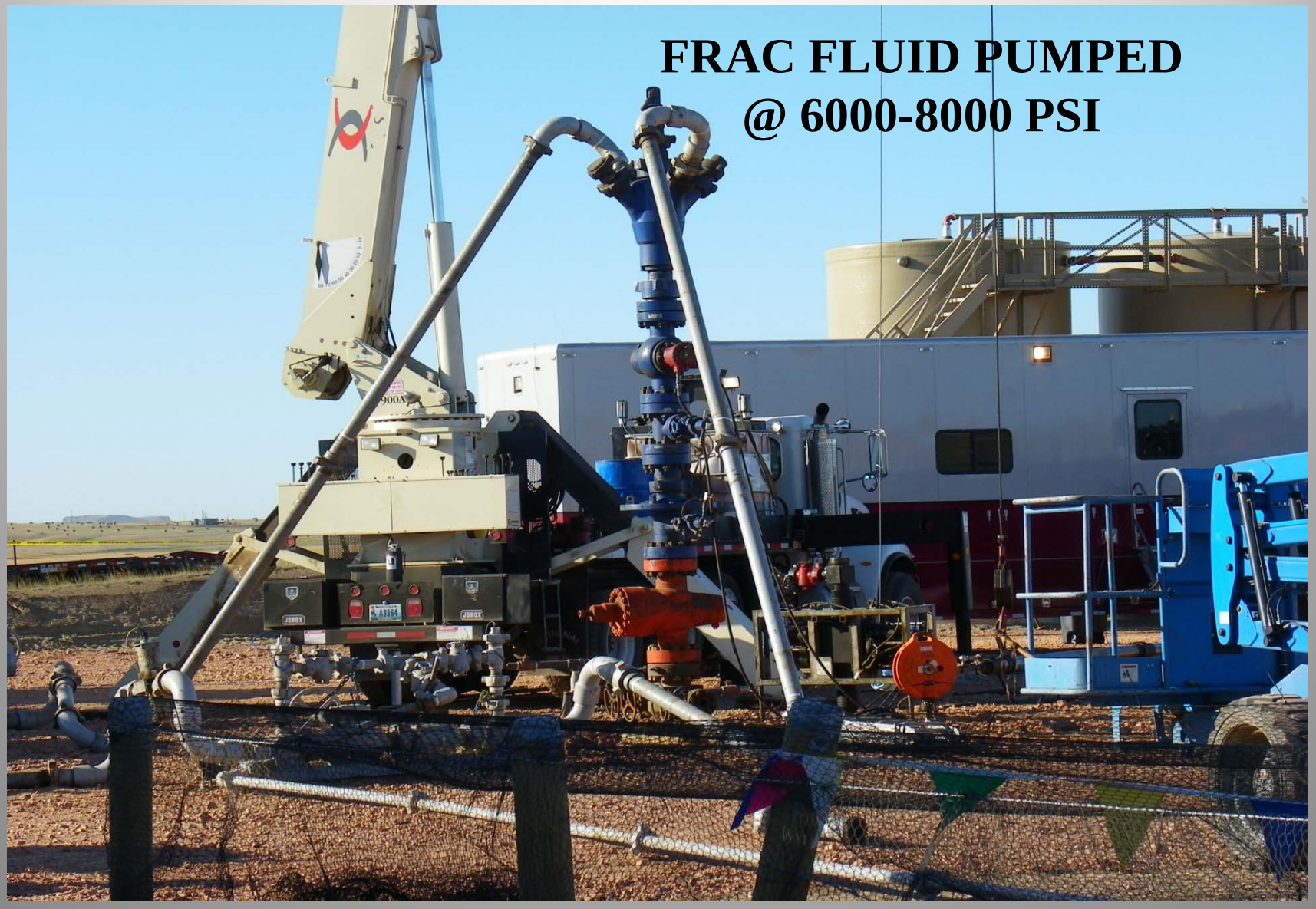
TRUCKS FILLING TRAILER TANKS
4 TRUCK LOADS PER 400 Bbl. TANK

400 BBL. TRAILER TANKS
Connected Inline

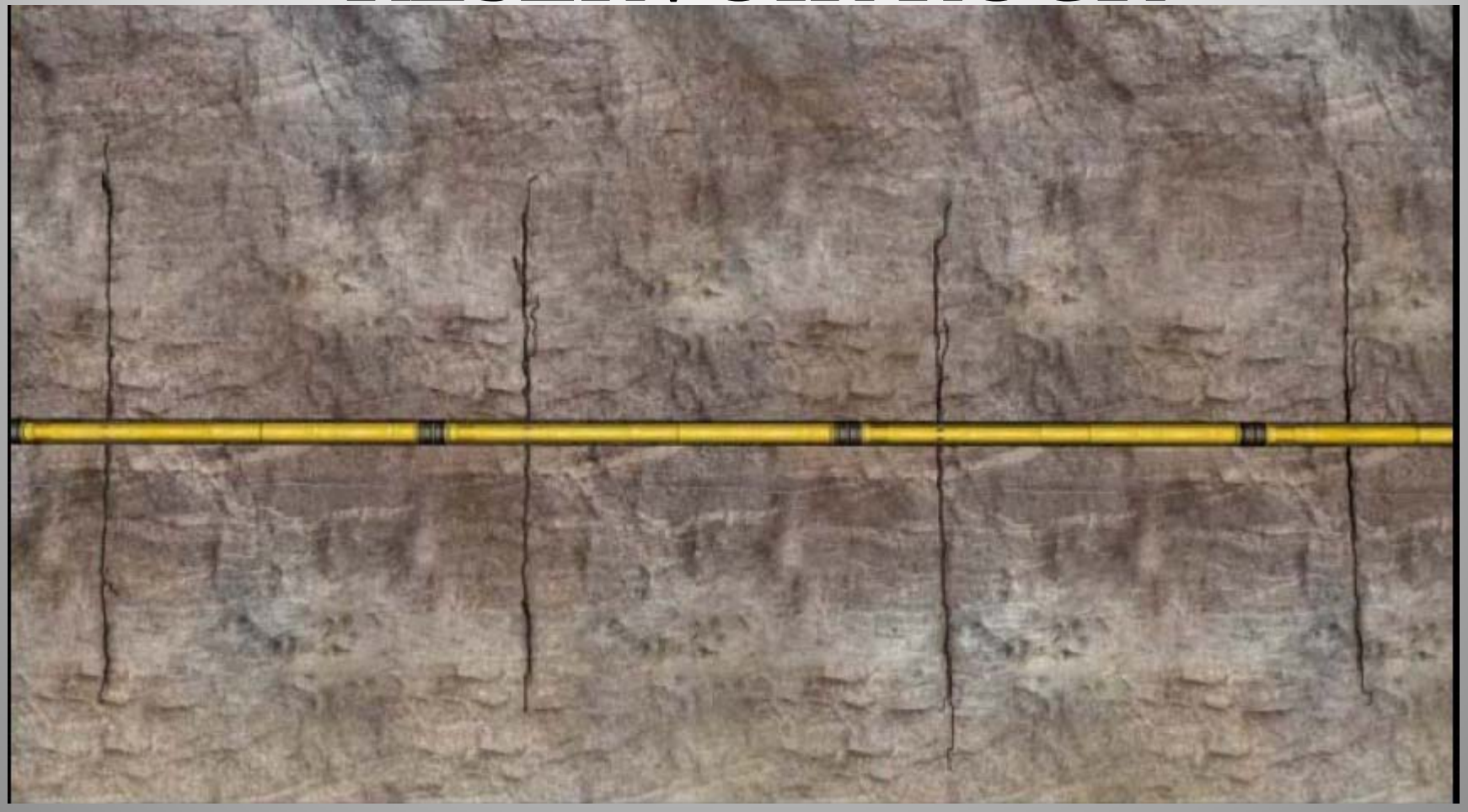
BLENDING FRAC FLUID

Blender (Sand, Water & Gel) ***Sand Conveyor***

FRAC STACK



FRACTURES INDUCED in RESERVOIR ROCK



FRAC FLUID FLOW BACK

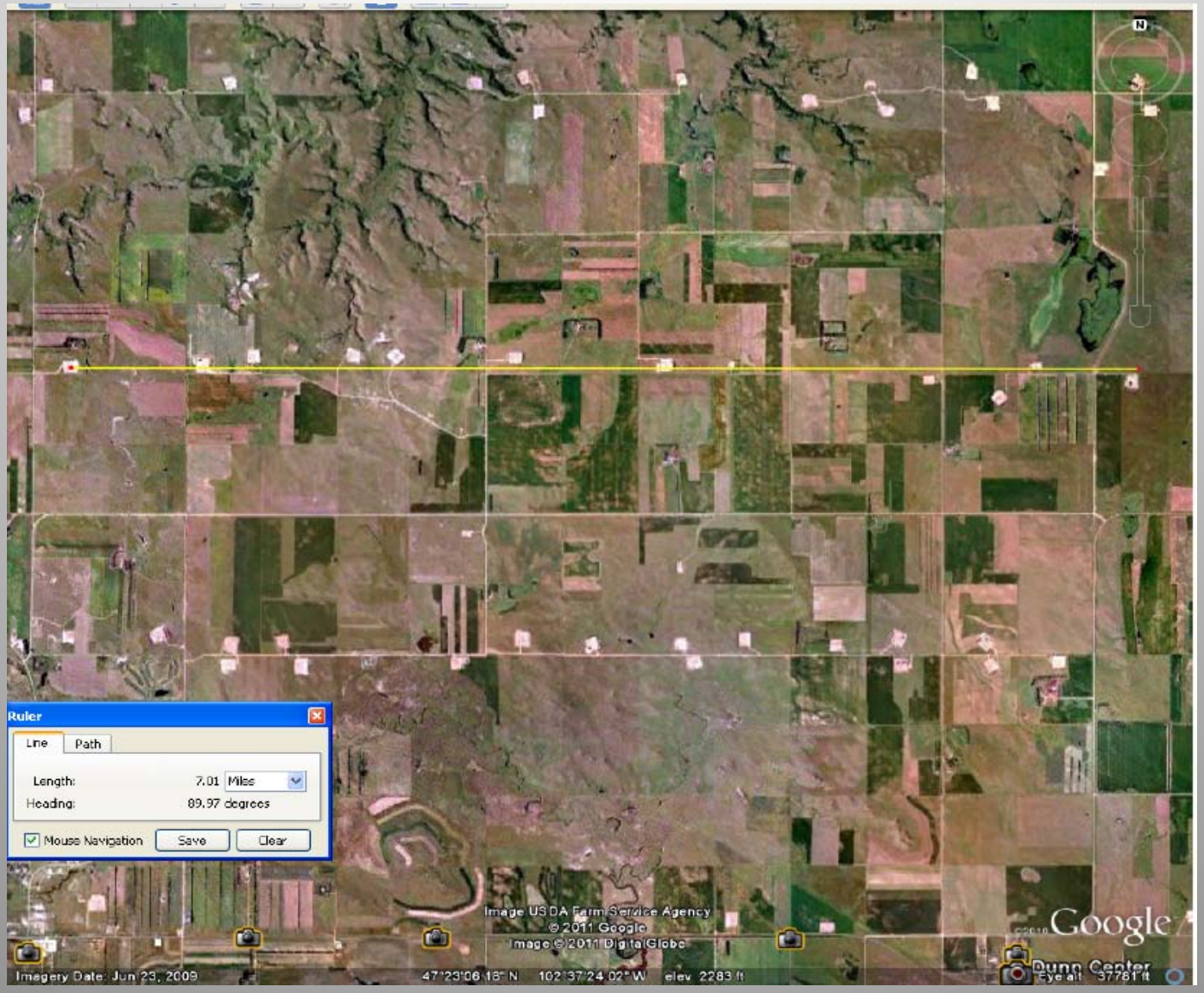
RECOVER 60-75% of FRAC FLUID

- Misc. Frac Statistics
  - Down hole temperature averages 200-250 degrees Fahrenheit.
  - Powdered gel is added to water to make the sand suspend in the water during the frac.
  - Water cannot be reused after frac and the recovered water is disposed of by trucking to a disposal well. (Usually Dakota Fm.)
  - You can expect an average of 280 to 440 truck loads of water, sand, and equipment for every frac job.
  - Estimated cost of a frac job is between $1.4 and 2.1 million.

EUR 2.1-2.6 Billion Barrels (Bakken)

DRILLING COST $5-7 Million

TOTAL WELL COST $6.5-9 Million


Ruler
Line
Path
Length:
7.01
Miles
Heading:
89.97 degrees
Mouse Navigation
Save
Clear
Image USDA Farm Service Agency
© 2011 Google
Image © 2011 DigitalGlobe
Google
Imagery Date: Jun 23, 2009
47°23'06.16" N 102°37'24.02" W elev 2283 ft
Dunn Center
Eye alt 37761 ft

Vern Whitten Photography

WATER NEEDS FOR BAKKEN

DEVELOPMENT

IN MONTANA

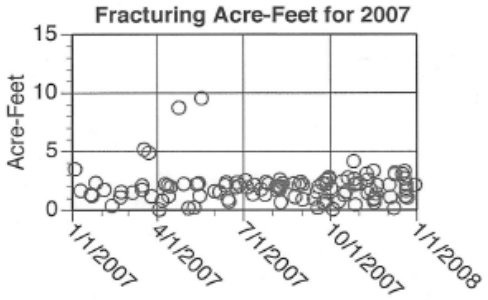
?

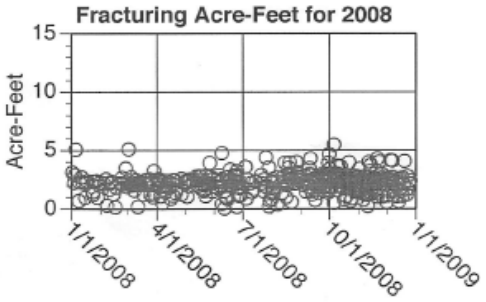
Fracturing Water used (Acre-Feet) at Bakken Oil Well Sites in North Dakota.

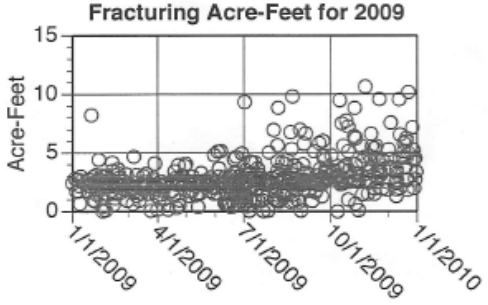
Year of Frac	Frac-Count	Total AcFt	Mean AcFt	Min. AcFt	Max. AcFt
2004	1	0.70	0.70	0.70	0.70
2005	2	3.06	1.53	0.89	2.17
2006	22	32.30	1.47	0.28	7.54
2007	112	219.31	1.96	0.05	9.55
2008	368	812.61	2.21	0.06	5.48
2009	481	1,360.41	2.83	0.02	10.66
2010	714	3,524.23	4.94	0.00	14.45
2011	78	414.74	5.32	0.92	9.56

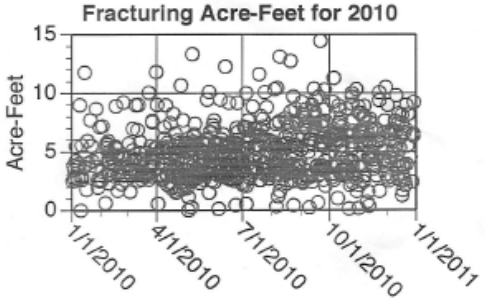
(Data Source: North Dakota Oil & Gas Division : March 29, 2011)

(Includes all confidential sites : Frac reporting is not required, so not all Frac jobs shown in totals.)









barrels per day (bbl/day)	million gallons per day (Mgd)	gallons per minute (gpm)	cubic feet per second (cfs)	cubic meters per second (m^3/s)
23,810	1.0	694.4	1.55	0.04381
34.3	0.00144	1.0	0.0022	0.00006
100	0.0042	2.9167	0.0065	0.000184

1 cubic meter = 1000 liters

1 acre = 43,560 square feet

Water Use Comparisons

Use	gallons (millions)	barrels (thousands)	acre-feet	cubic meters
Typical **Daily** Use for a 50,000-Person Midwestern City	10	238.1	30.7	37,850
Daily Pumping Volume for a Center-Pivot Irrigator for 130 Acres (irrigated portion of ¼ section)	1.008	24	3.1	3815
Average **Daily** Water Withdrawal for Once-Through Cooling at a 400-MW Coal-Fired Power Plant	365	8691	1120	1,381,525
Water Used to Fracture the Formation for an Oil Well in the Bakken Formation (**one-time use**)	0.5–1.0	11.9–23.8	1.5–3.1	1893–3785
Proposed Maximum **Daily** Volume of Water Imported for the Red River Valley Water Supply Project	77.56	1,847	238	293,556

FACTORS

RATE OF DEVELOPMENT

WATER AVAILABILITY

TECHNOLOGY CHANGES

POTENTIAL SOURCES

SURFACE WATER

- MISSOURI RIVER
- YELLOWSTONE RIVER

GROUNDWATER

- GLACIAL OUTWASH AQUIFERS
- ALLUVIAL AQUIFERS

POSSIBLE OPTIONS

1. AVOID COMPETITION WITH FRESH WATER SUPPLIES (MAY BE PROMISING)

2. FOX HILLS- HELL CREEK (BAD IDEA)

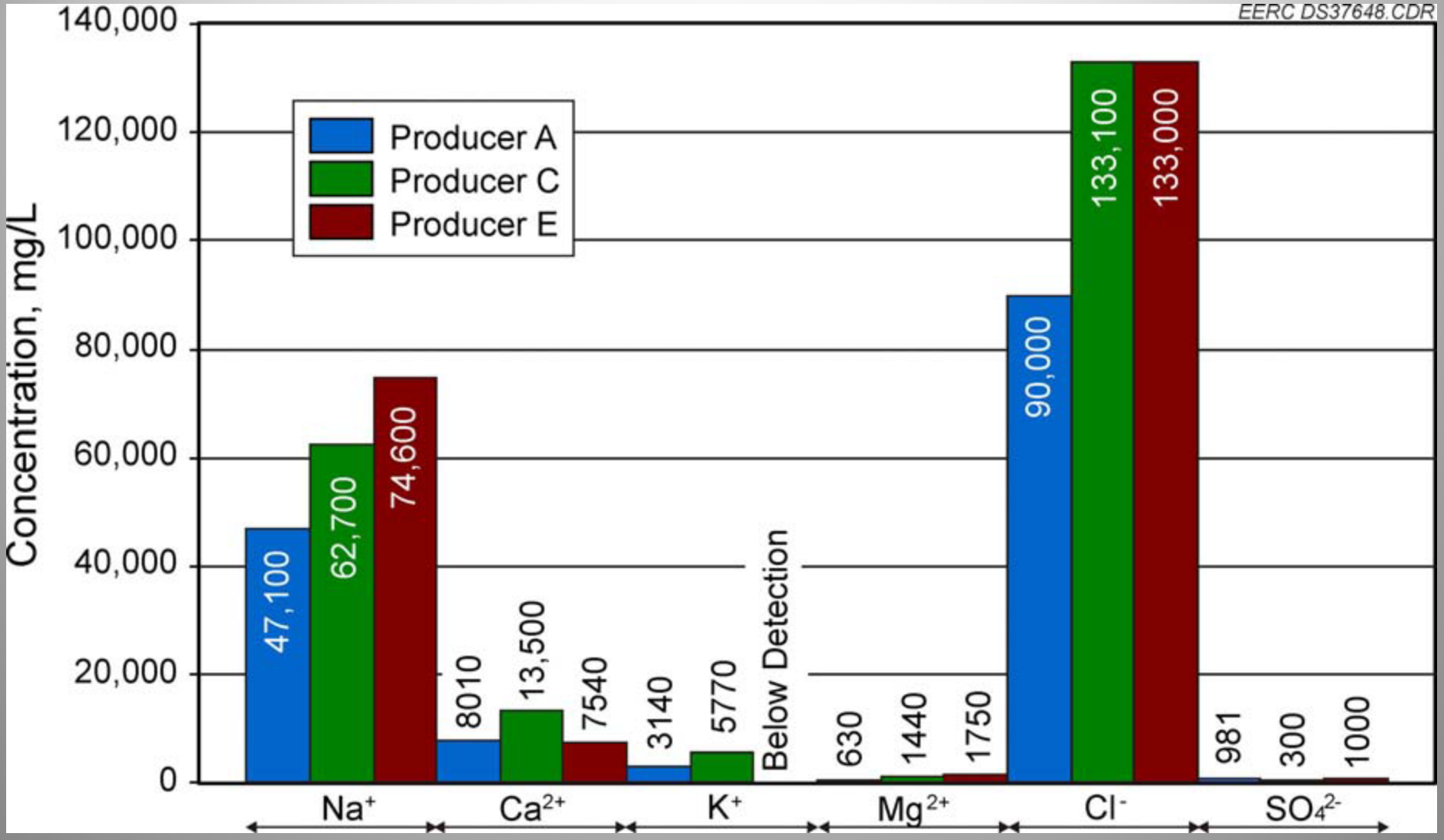
WATER QUALITY ISSUES

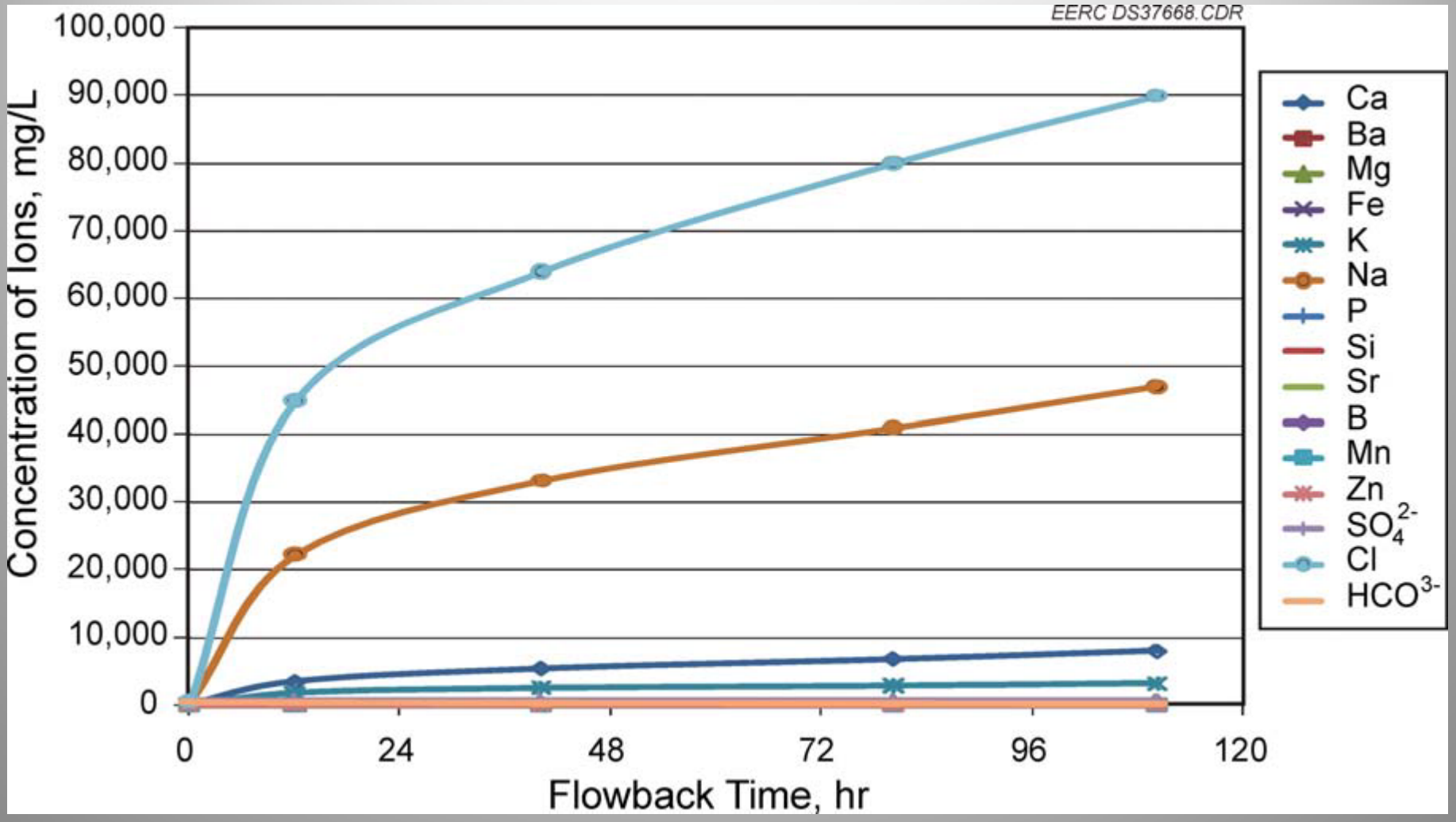
1. FLOWBACK WATER IS SIMILAR TO PRODUCED WATER
   (EERC 2010)
   10X SEAWATER SALINITY

2. LEAKS AND SPILLS NEED TO BE ELIMINATED

3. CEMENT BOND LOGS

FLOWBACK WATER QUALITY (EERC)





Changes in specific constituent concentration in frac flowback water versus time. (EERC)

BASELINE CONDITIONS

ROOSEVELT COUNTY 2011

10 SAMPLES
FULL ANALYSES + TPH

DIESEL RANGE ORGANICS
IN 5 SAMPLES

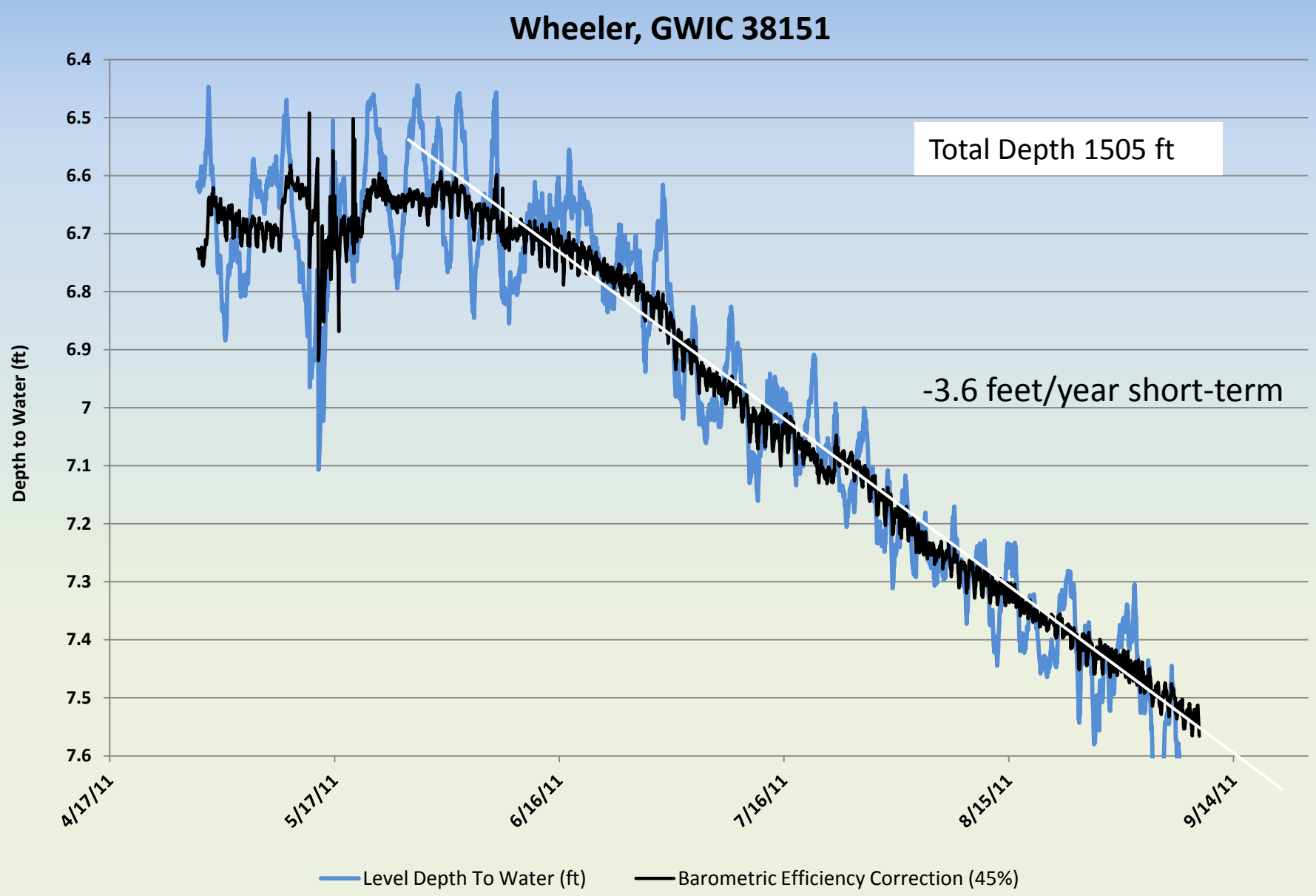
HIGH LEVELS OF NACL
NOT FOUND

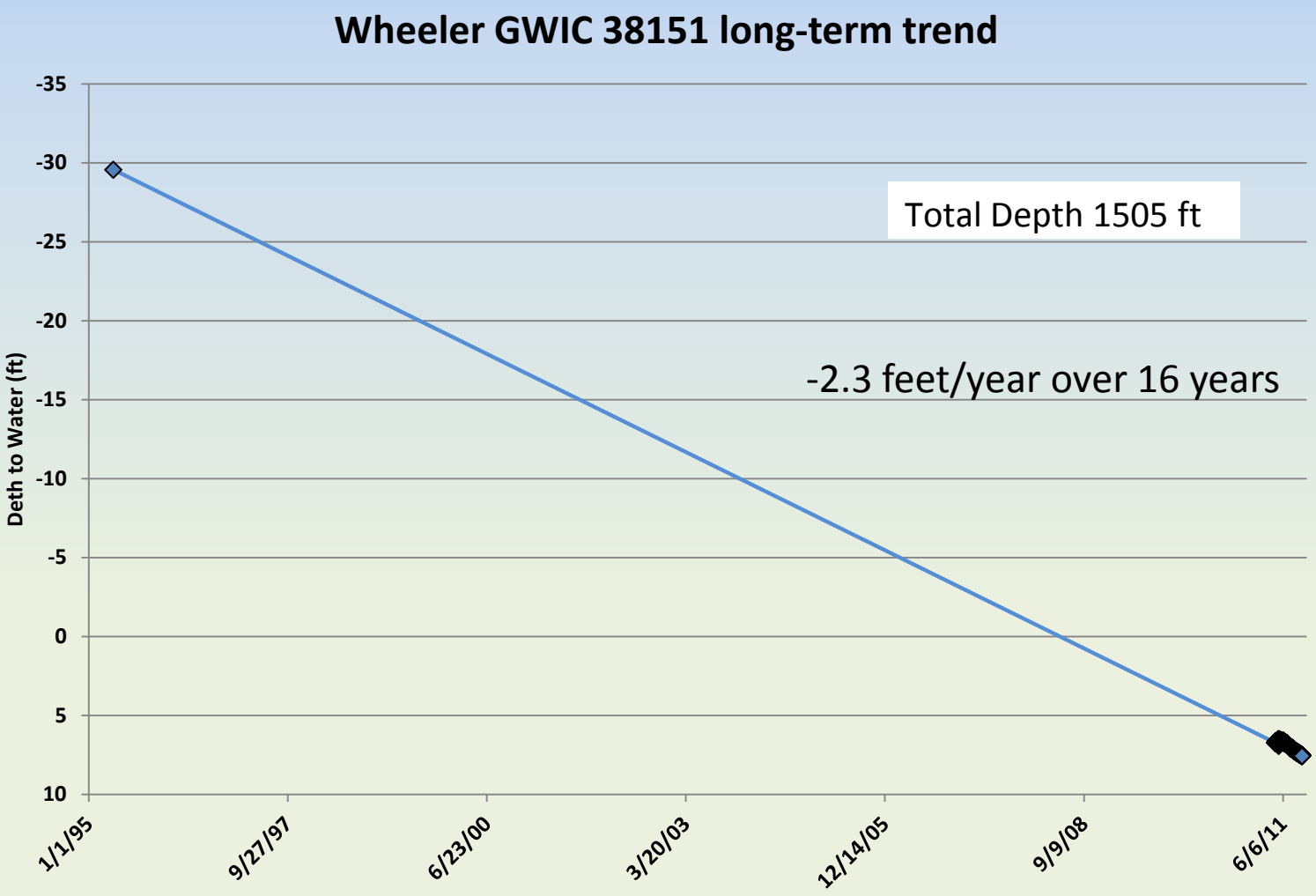
Fox Hills/Hell Creek Aquifer Monitoring

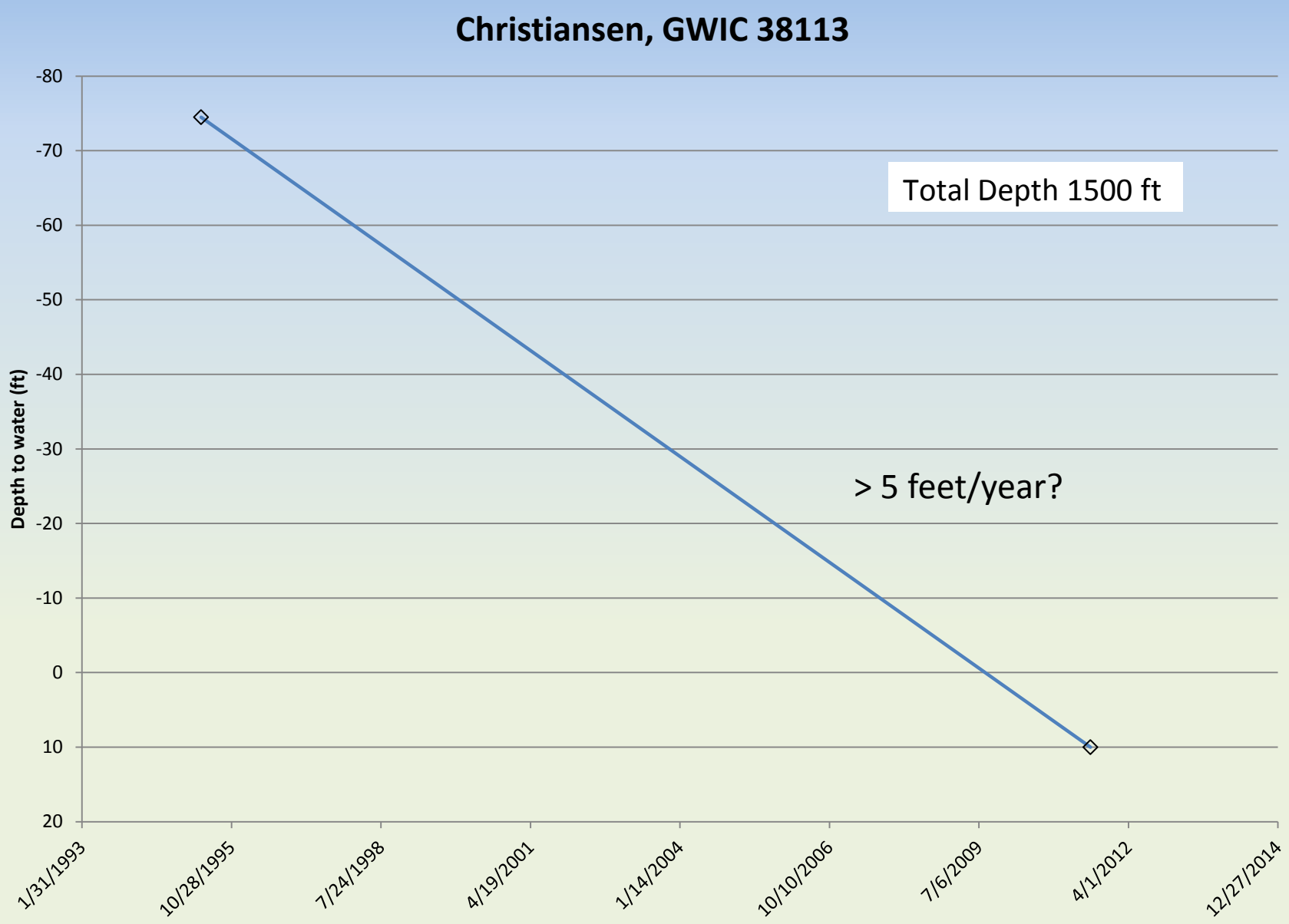
Data logger installation
in wells near Sidney, MT
February 2011

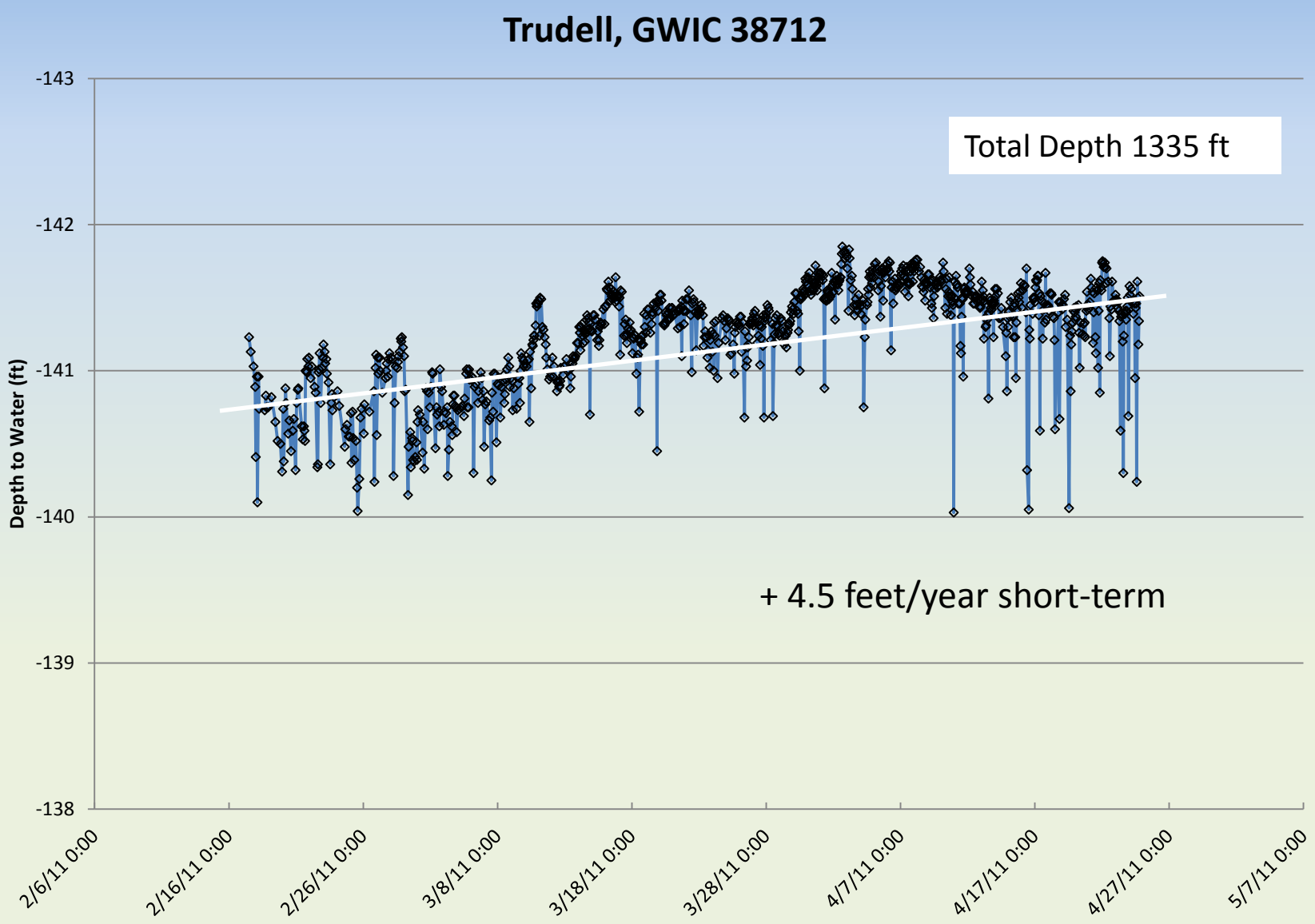
173659 Anderson West
39461 Anderson East
MT
ND
Trudell 38712
N
Christiansen
Wheeler 38151
10 Miles
Fairview

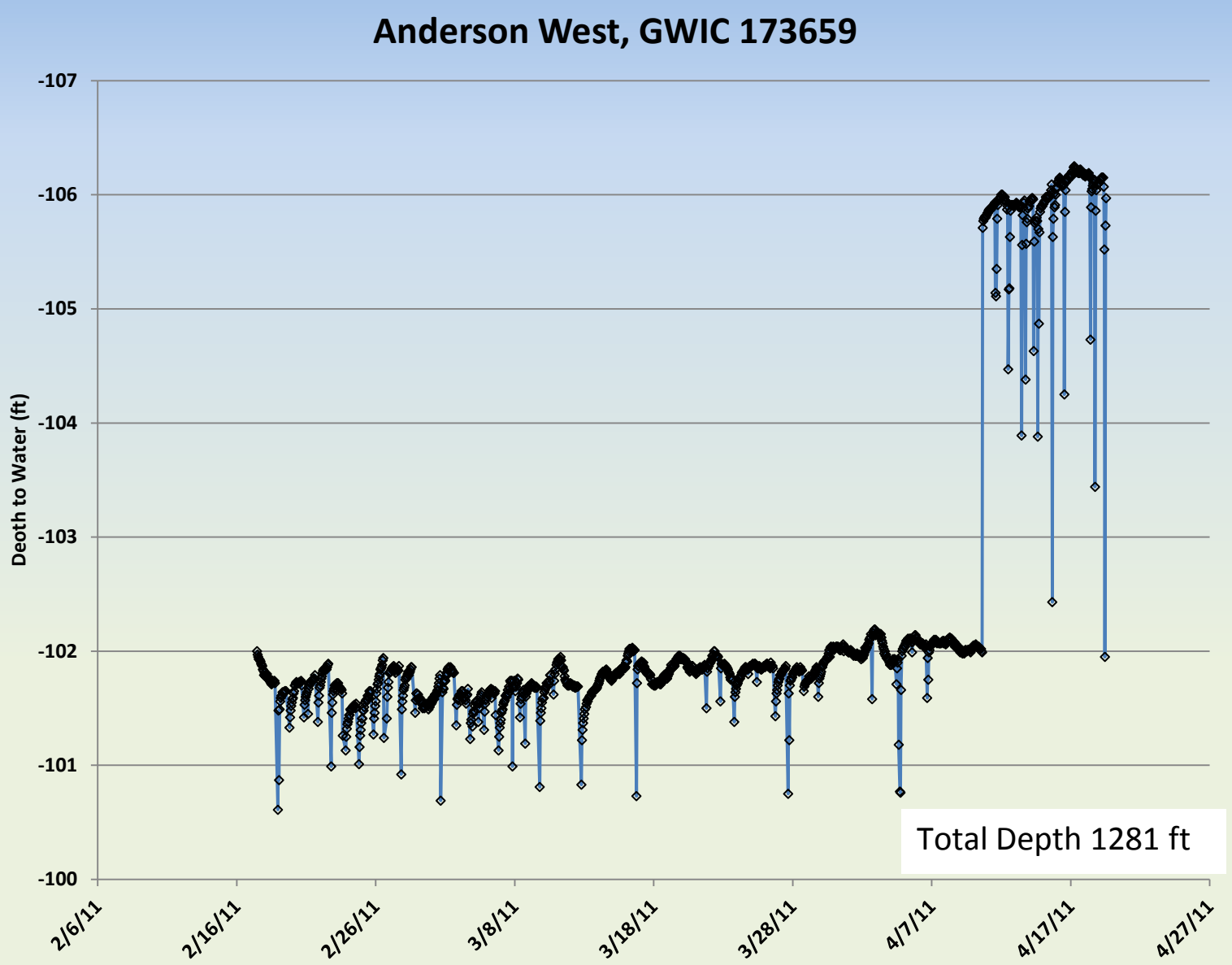
Data logger installation in flowing wells.

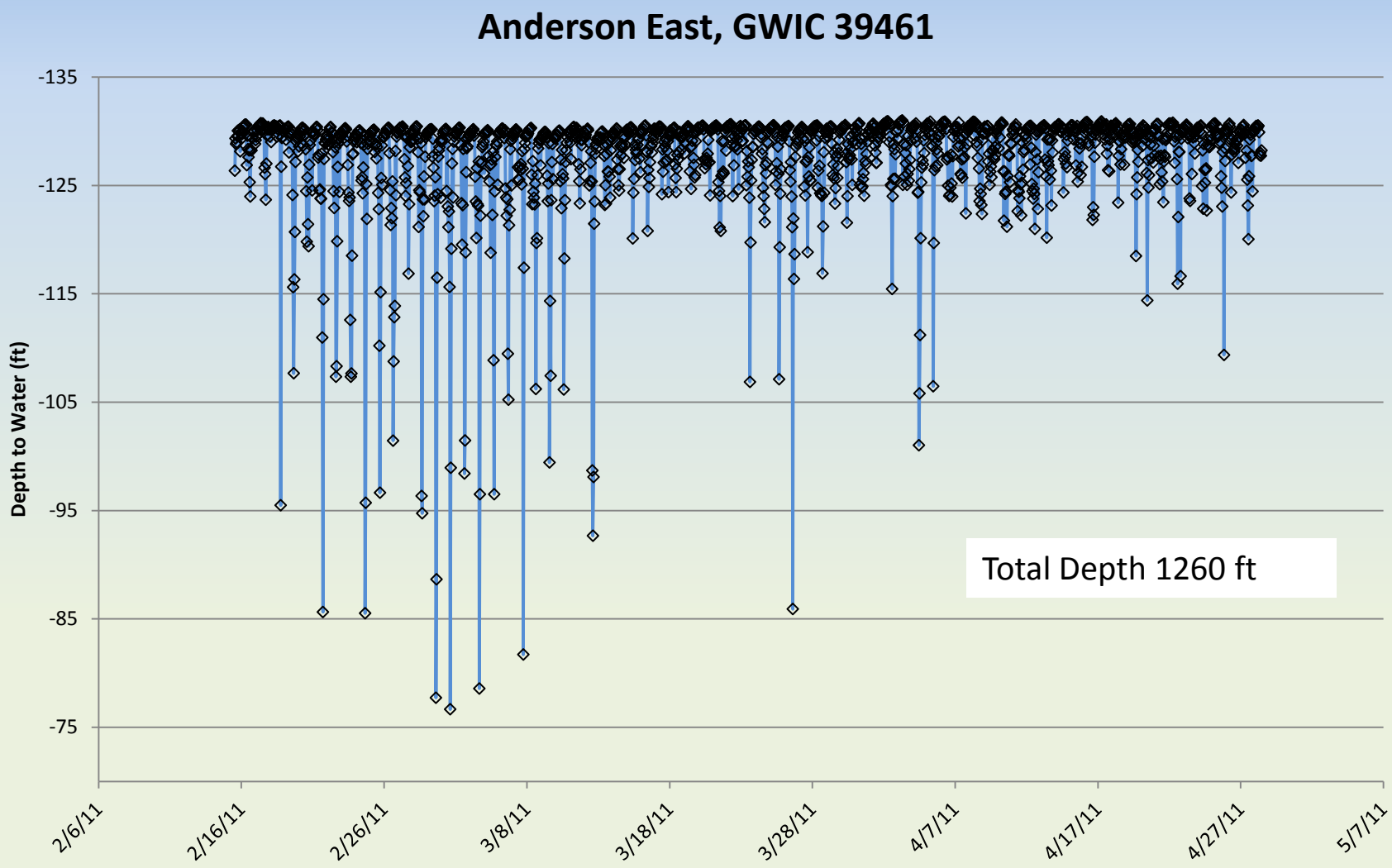

Wheeler, GWIC 38151
Total Depth 1505 ft
-3.6 feet/year short-term
Depth to Water (ft)
6.4
6.5
6.6
6.7
6.8
6.9
7
7.1
7.2
7.3
7.4
7.5
7.6
4/17/11
5/17/11
6/16/11
7/16/11
8/15/11
9/14/11
Level Depth To Water (ft)
Barometric Efficiency Correction (45%)

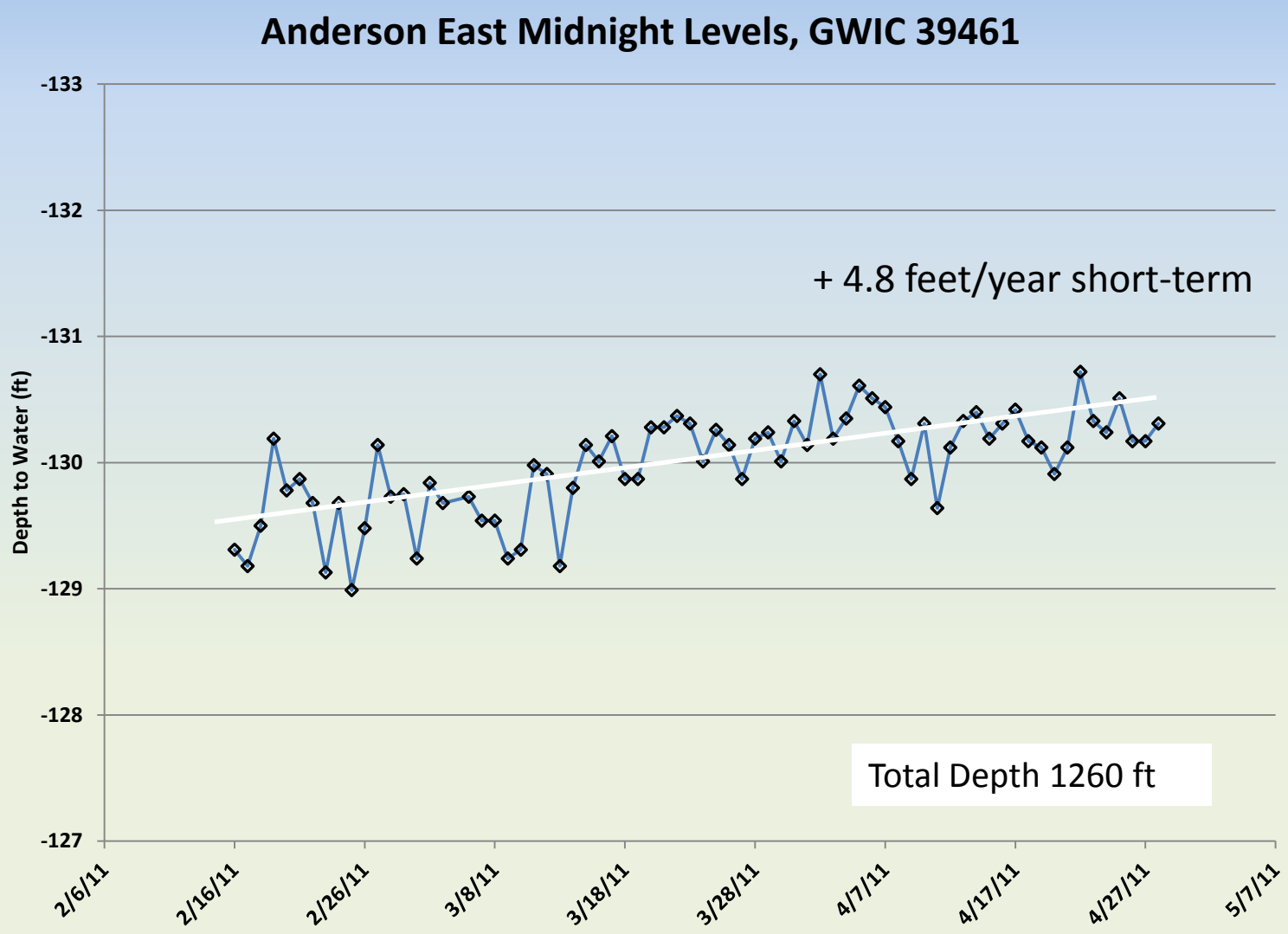

Wheeler GWIC 38151 long-term trend
Deth to Water (ft)
-35
-30
-25
-20
-15
-10
-5
0
5
10
1/1/95
9/27/97
6/23/00
3/20/03
12/14/05
9/9/08
6/6/11
Total Depth 1505 ft
-2.3 feet/year over 16 years

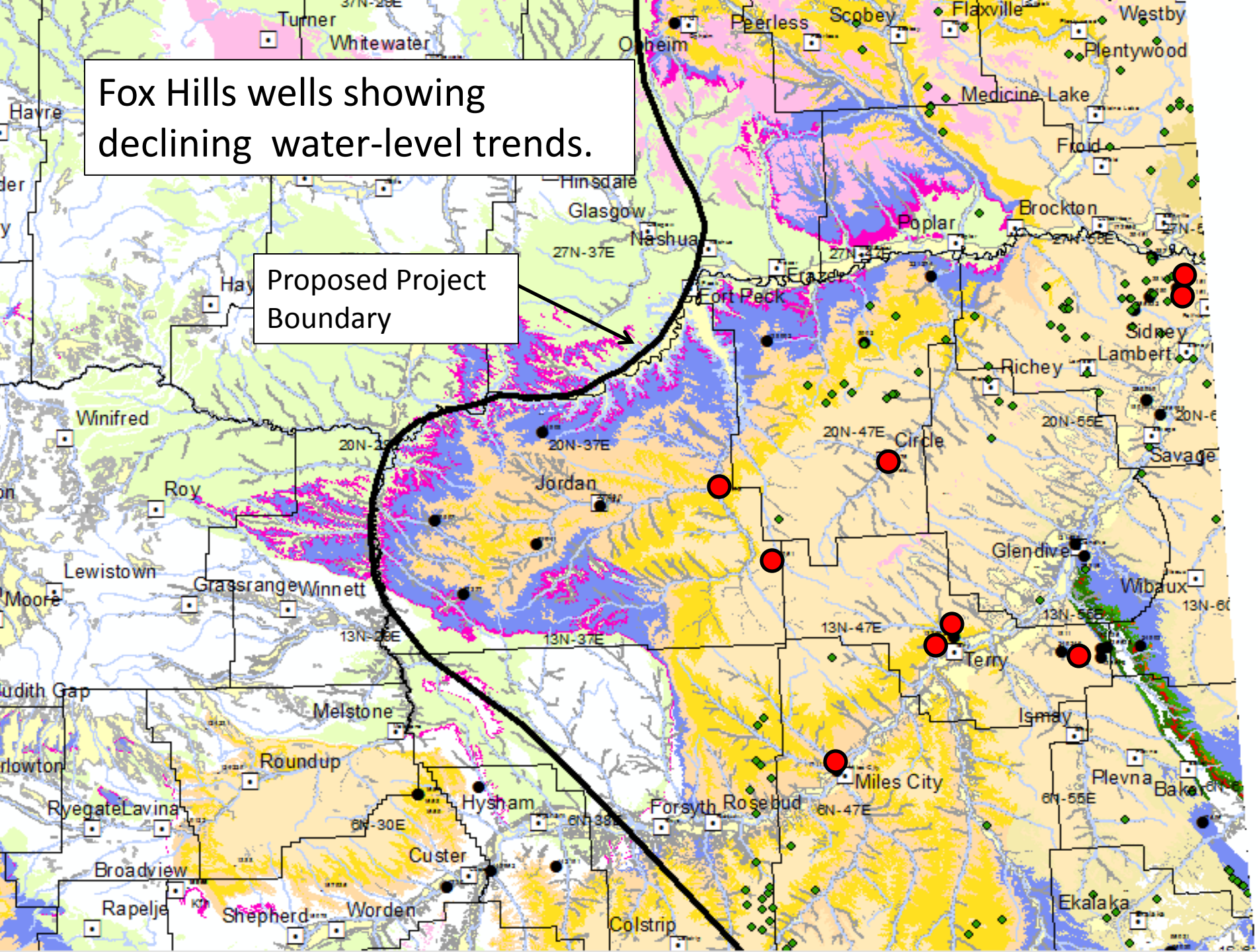

Christiansen, GWIC 38113
Depth to water (ft)
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014
Total Depth 1500 ft
> 5 feet/year?

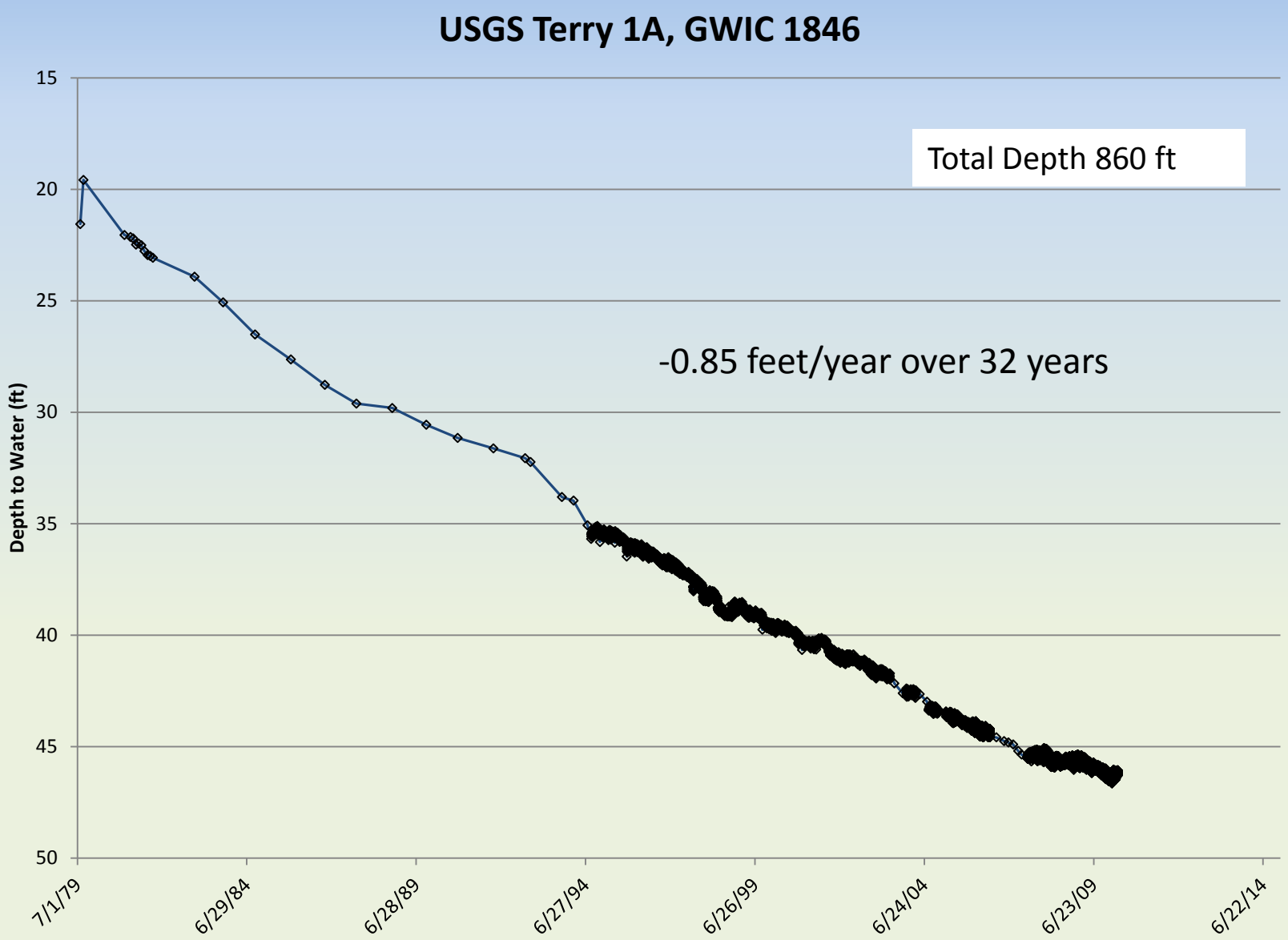

Trudell, GWIC 38712
Total Depth 1335 ft
+ 4.5 feet/year short-term
Depth to Water (ft)
-143
-142
-141
-140
-139
-138
2/6/11 0:00
2/16/11 0:00
2/26/11 0:00
3/8/11 0:00
3/18/11 0:00
3/28/11 0:00
4/7/11 0:00
4/17/11 0:00
4/27/11 0:00
5/7/11 0:00

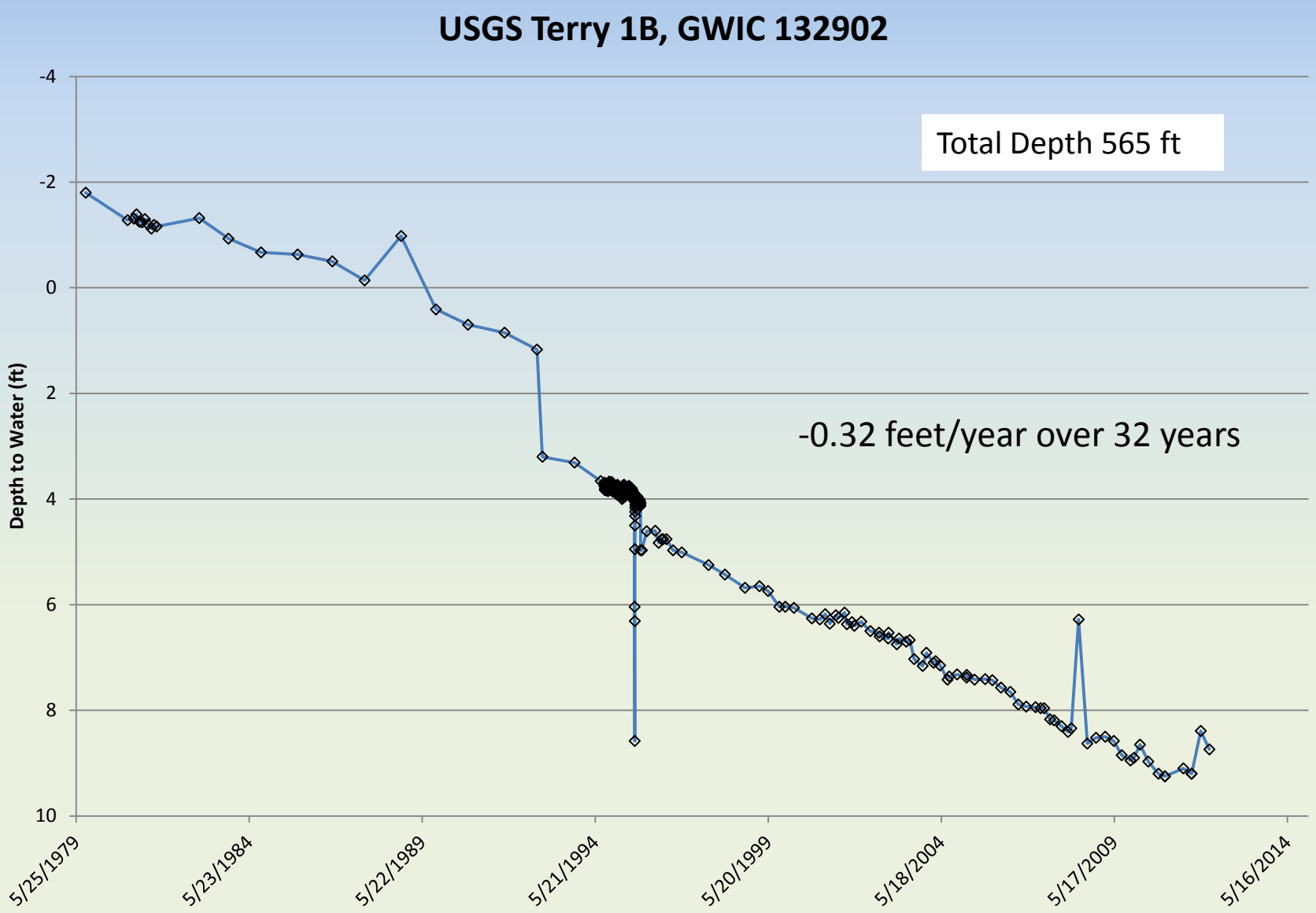

Anderson West, GWIC 173659
Deoth to Water (ft)
-107
-106
-105
-104
-103
-102
-101
-100
2/6/11
2/16/11
2/26/11
3/8/11
3/18/11
3/28/11
4/7/11
4/17/11
4/27/11
Total Depth 1281 ft


Anderson East, GWIC 39461
Depth to Water (ft)
-135
-125
-115
-105
-95
-85
-75
2/6/11
2/16/11
2/26/11
3/8/11
3/18/11
3/28/11
4/7/11
4/17/11
4/27/11
5/7/11
Total Depth 1260 ft

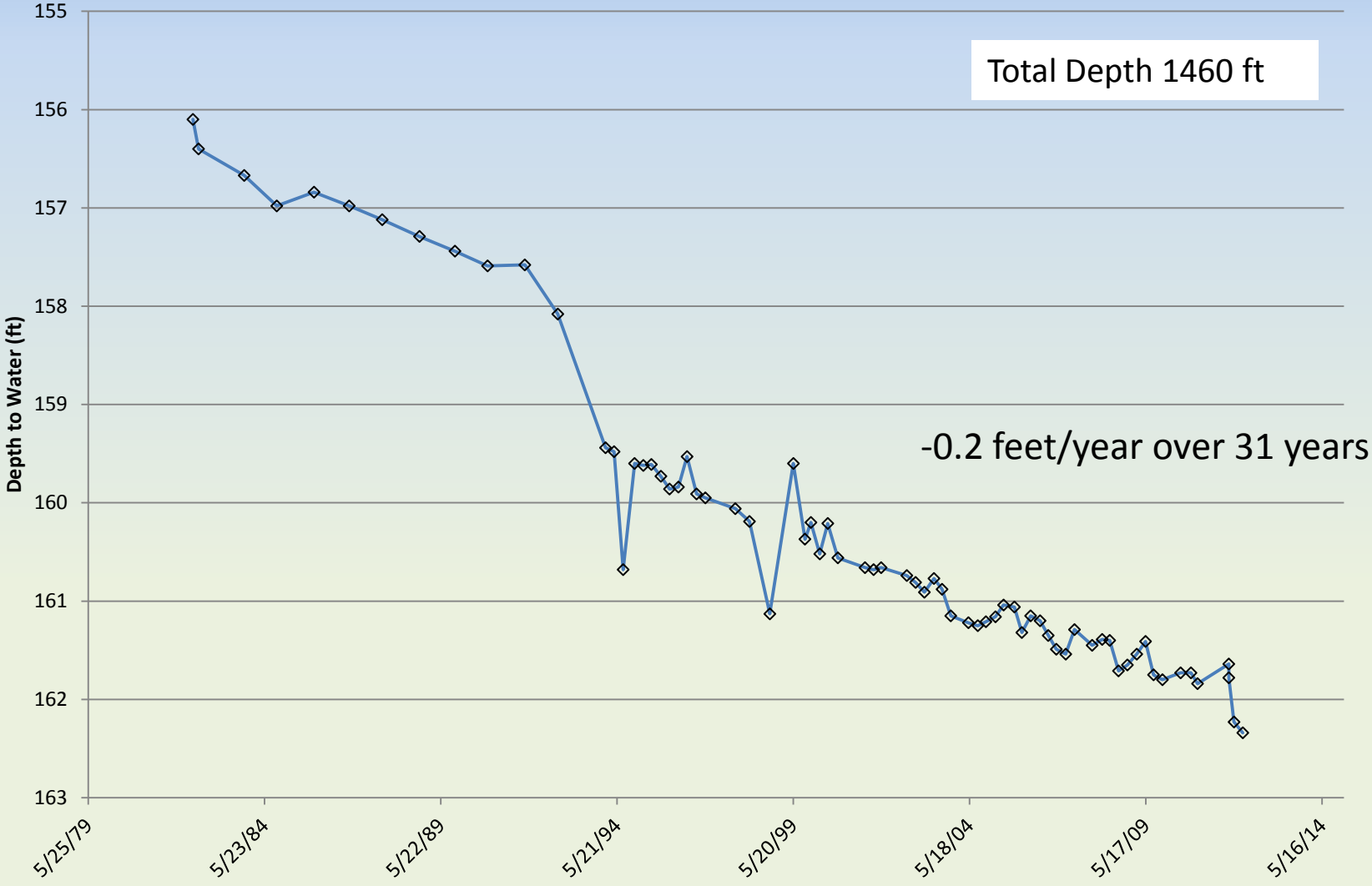

Anderson East Midnight Levels, GWIC 39461
-133
-132
-131
-130
-129
-128
-127
Depth to Water (ft)
+ 4.8 feet/year short-term
Total Depth 1260 ft
2/6/11
2/16/11
2/26/11
3/8/11
3/18/11
3/28/11
4/7/11
4/17/11
4/27/11
5/7/11

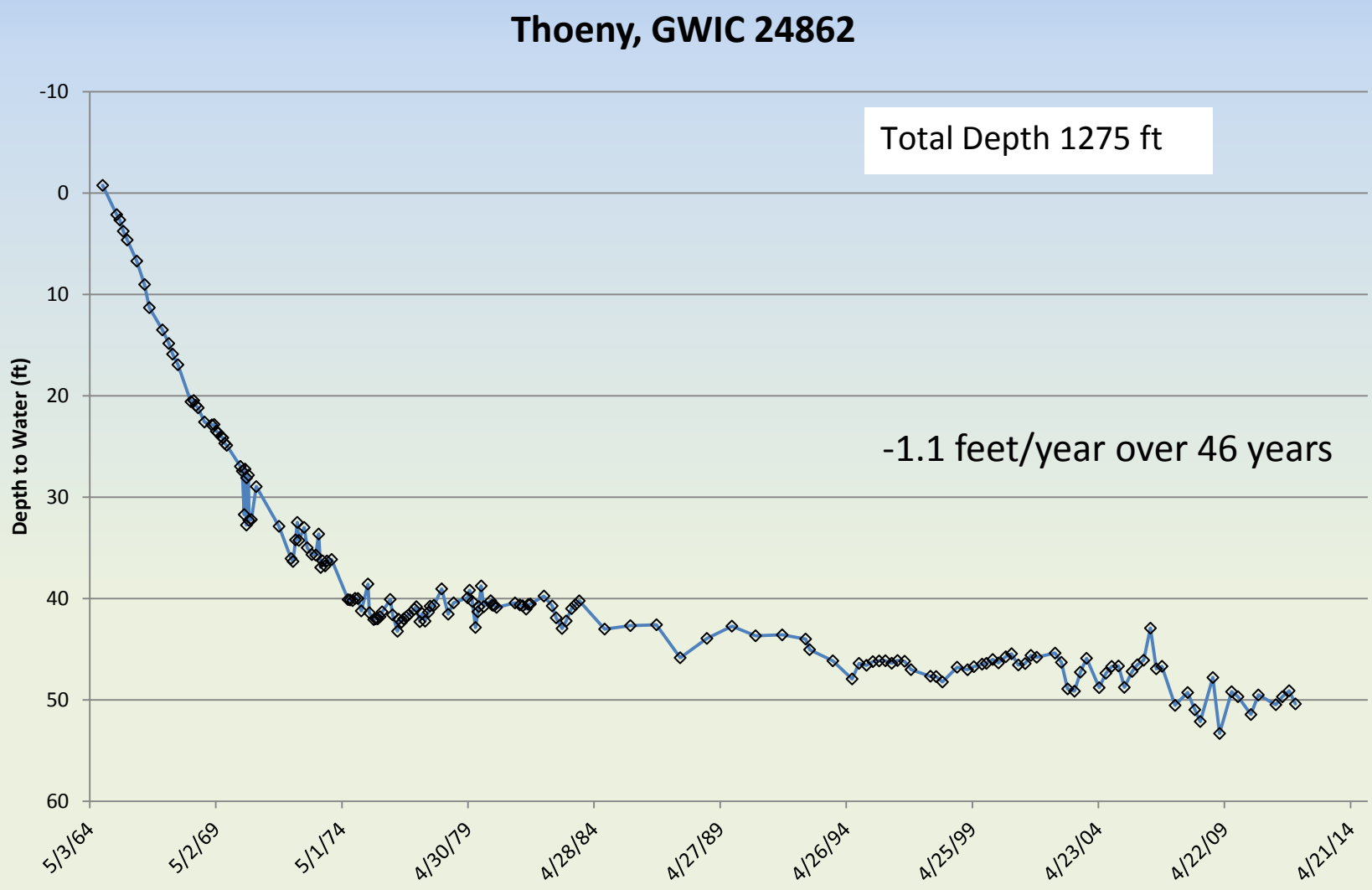

Fox Hills wells showing declining water-level trends.
Proposed Project Boundary
Turner
Whitewater
Opheim
Peerless
Scobey
Flaxville
Westby
Plentywood
Medicine Lake
Froid
Havre
Hinsdale
Glasgow
Nashua
27N-37E
Poplar
Brockton
Fraser
Fort Peck
Sidney
Lambert
Richey
Winifred
20N-37E
20N-47E
Circle
20N-55E
Savage
Roy
Jordan
Glendive
Lewistown
Grassrange
Winnett
Wibaux
13N-37E
13N-47E
Terry
Judith Gap
Melstone
Ismay
Roundup
Miles City
Plevna
Baker
Ryegate
Lavina
Hysham
Forsyth
Rosebud
6N-30E
6N-47E
6N-55E
Custer
Broadview
Rapelje
Shepherd
Worden
Colstrip
Ekalaka


USGS Terry 1A, GWIC 1846
Total Depth 860 ft
-0.85 feet/year over 32 years
Depth to Water (ft)
15
20
25
30
35
40
45
50
7/1/79
6/29/84
6/28/89
6/27/94
6/26/99
6/24/04
6/23/09
6/22/14


USGS Terry 1B, GWIC 132902
Total Depth 565 ft
-0.32 feet/year over 32 years
Depth to Water (ft)
-4
-2
0
2
4
6
8
10
5/25/1979
5/23/1984
5/22/1989
5/21/1994
5/20/1999
5/18/2004
5/17/2009
5/16/2014

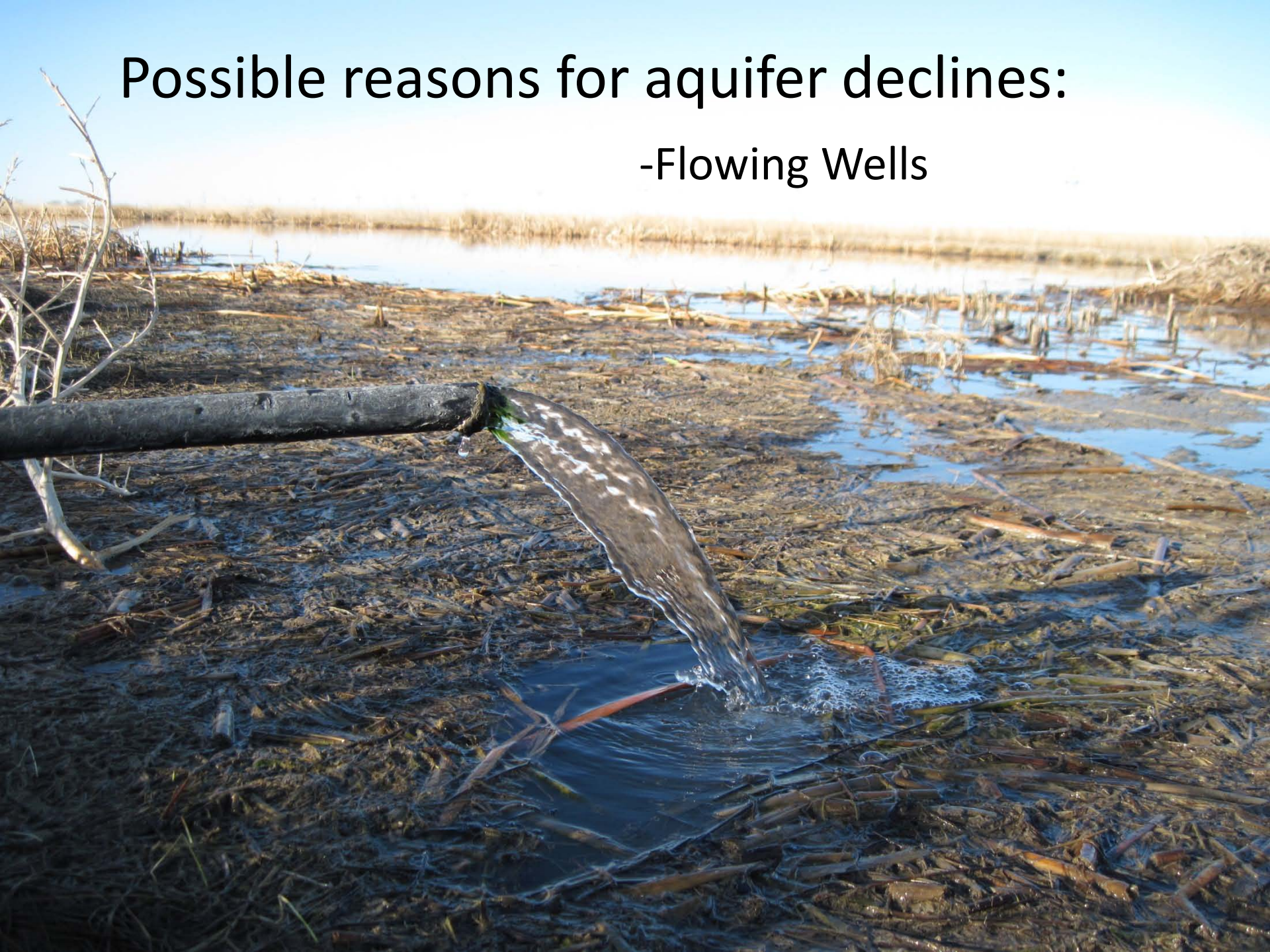
Bulington Northern BNTC-801, GWIC 2061




Thoeny, GWIC 24862
Total Depth 1275 ft
-1.1 feet/year over 46 years
Depth to Water (ft)
-10
0
10
20
30
40
50
60
5/3/64
5/2/69
5/1/74
4/30/79
4/28/84
4/27/89
4/26/94
4/25/99
4/23/04
4/22/09
4/21/14

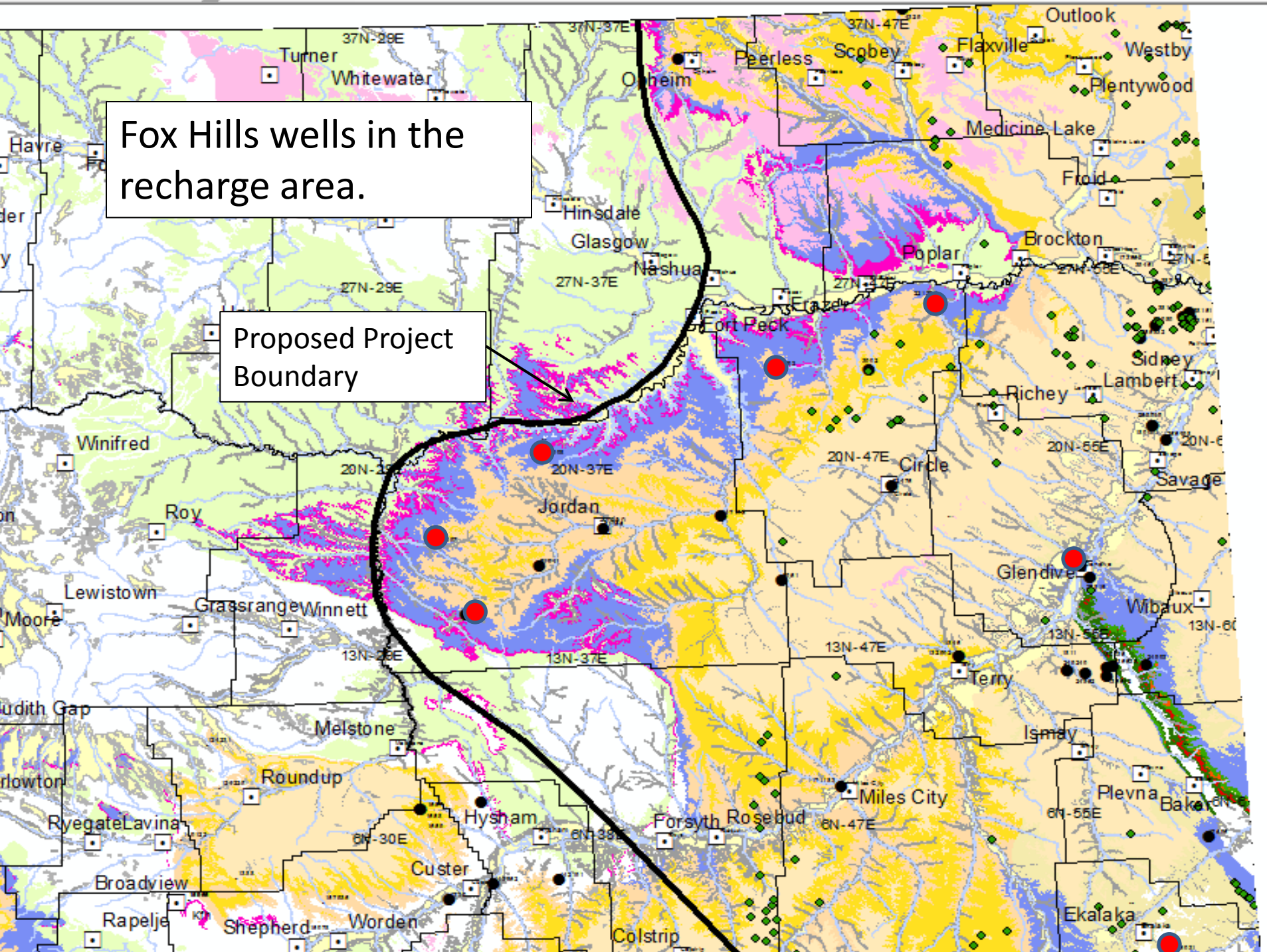
Possible reasons for aquifer declines:

-Flowing Wells

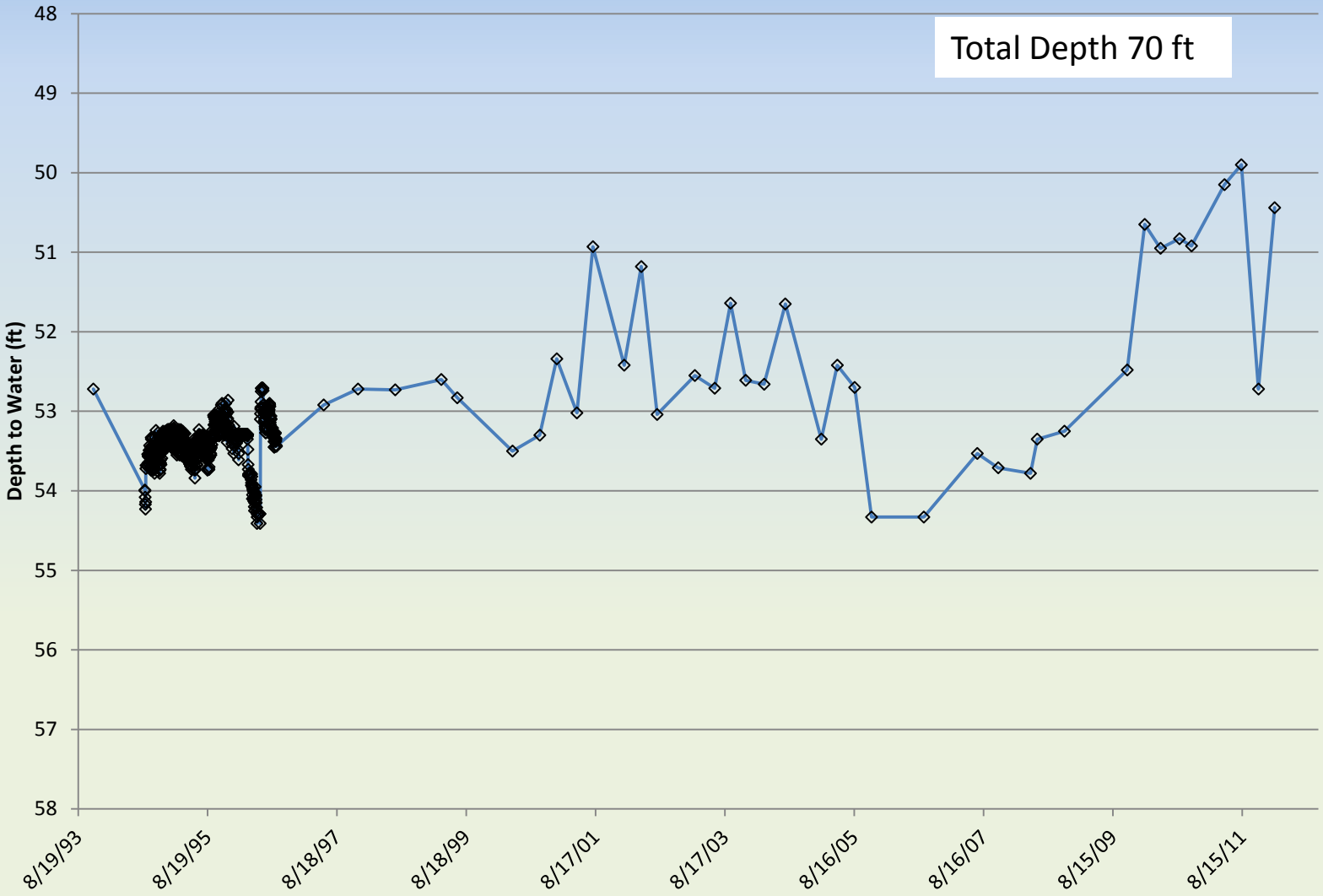


-New industrial use

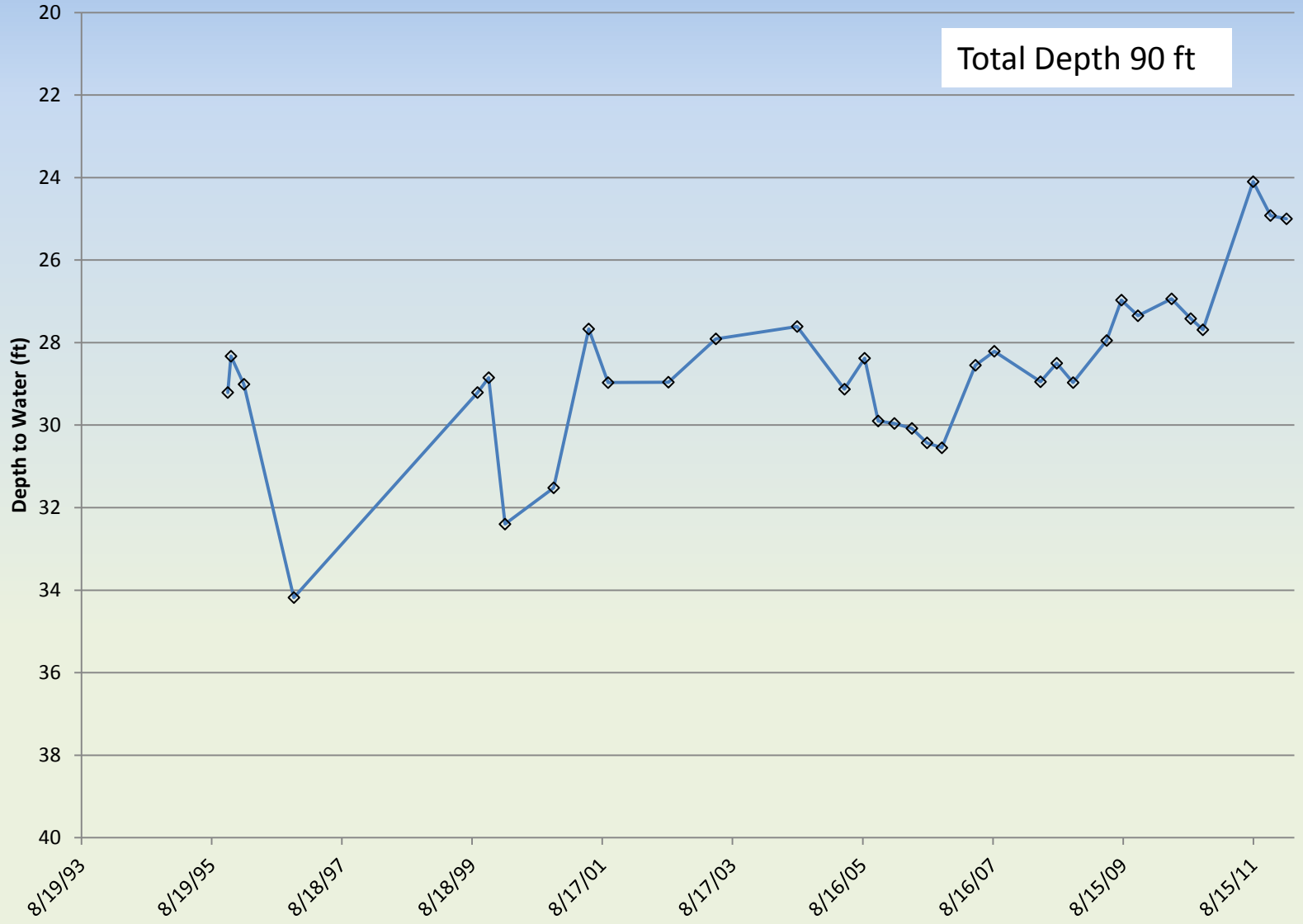
Recharge Area Hydrographs

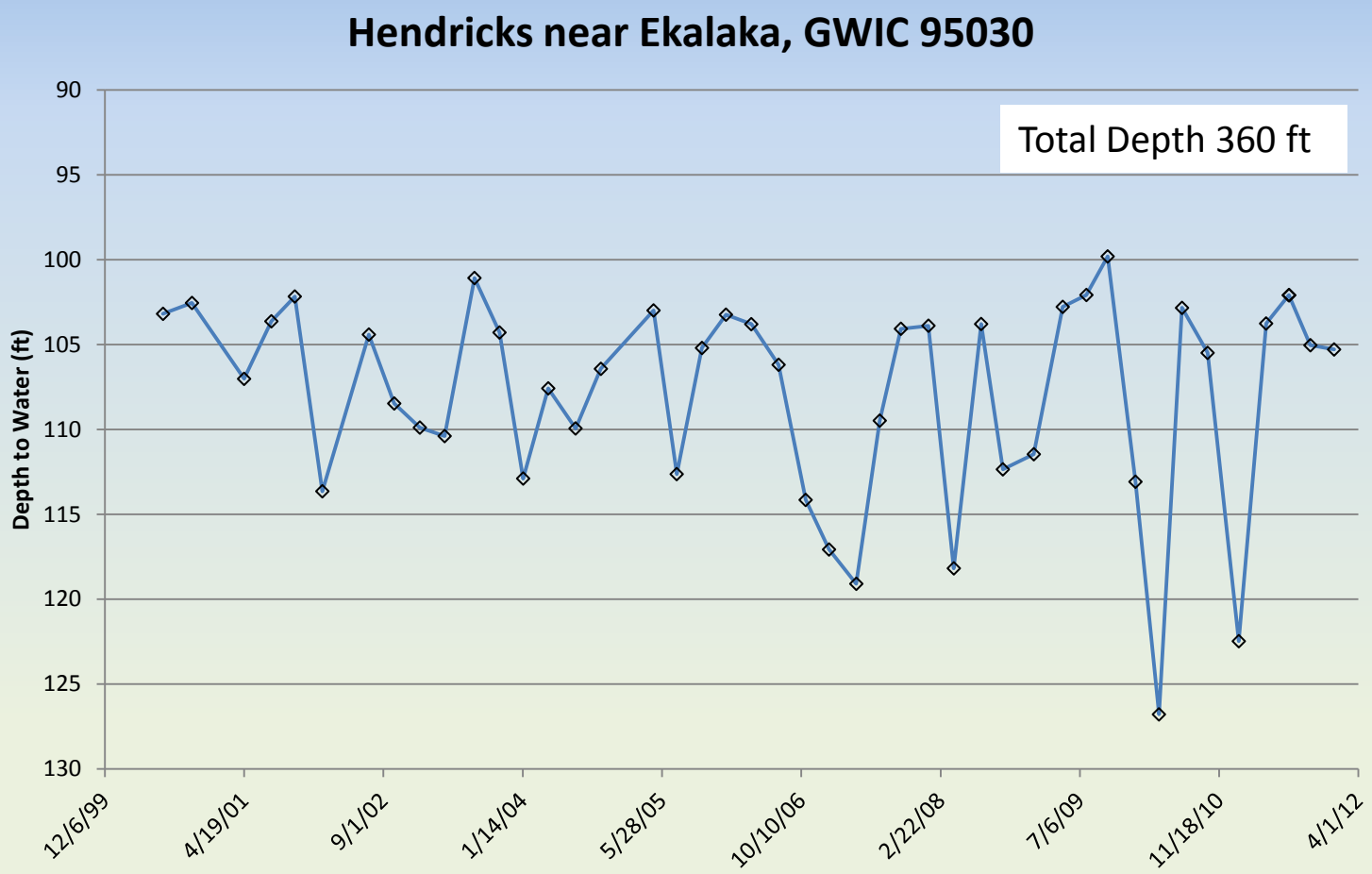

Fox Hills wells in the recharge area.
Proposed Project Boundary
Turner
Whitewater
Havre
Opheim
Peerless
Scobey
Flaxville
Outlook
Westby
Plentywood
Medicine Lake
Froid
Hinsdale
Glasgow
Nashua
Poplar
Brockton
Fort Peck
Sidney
Lambert
Richey
Winifred
Circle
Savage
Jordan
Roy
Glendive
Wibaux
Lewistown
Grassrange
Winnett
Moore
Terry
Judith Gap
Melstone
Ismay
Roundup
Miles City
Plevna
Baker
Ryegate
Lavina
Hysham
Forsyth
Rosebud
Custer
Broadview
Rapelje
Shepherd
Worden
Colstrip
Ekalaka
37N-29E
37N-37E
37N-47E
27N-29E
27N-37E
27N-47E
27N-55E
20N-37E
20N-47E
20N-55E
13N-37E
13N-47E
6N-30E
6N-47E
6N-55E

MT State Highway Department at Glendive, GWIC 121589

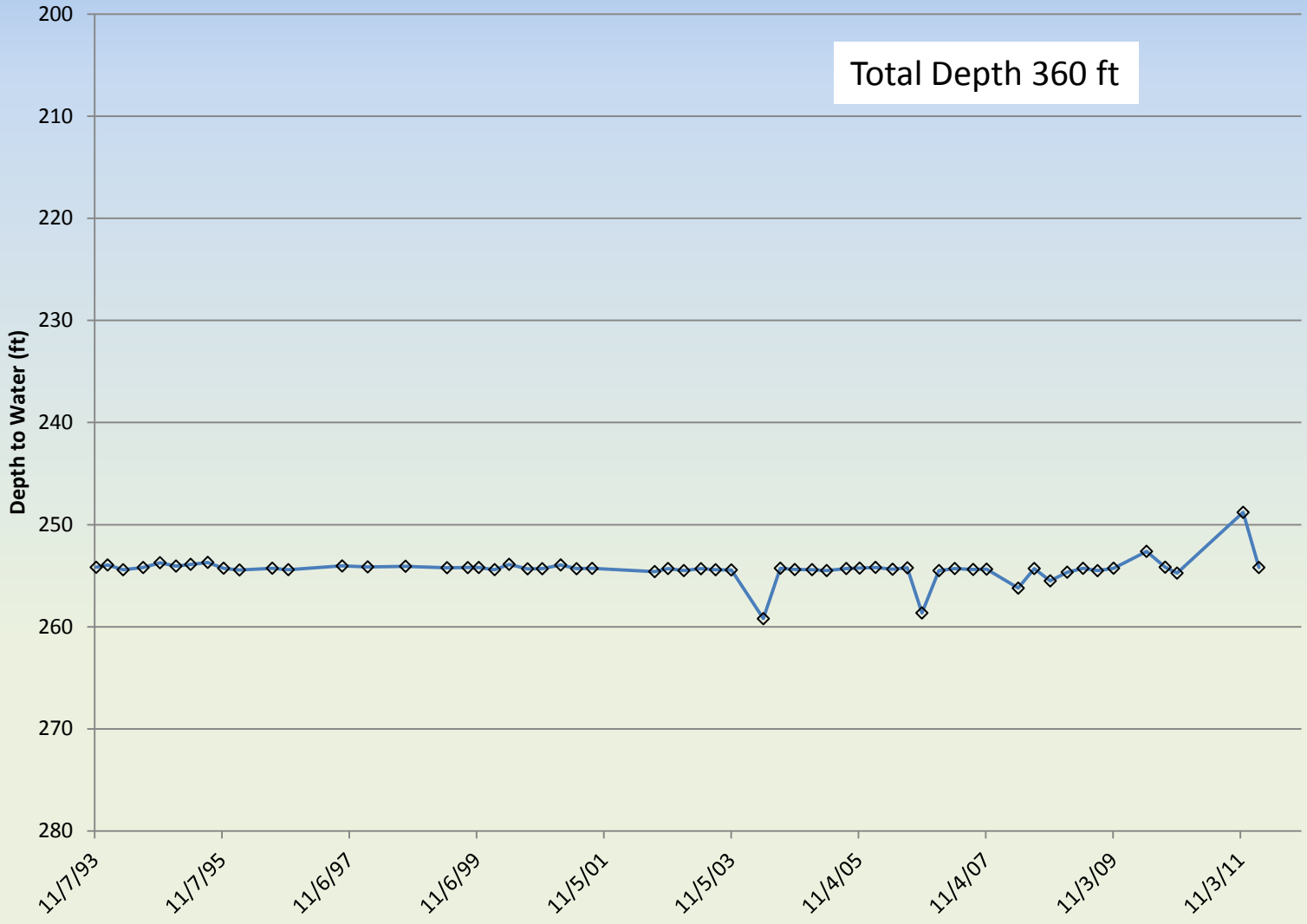


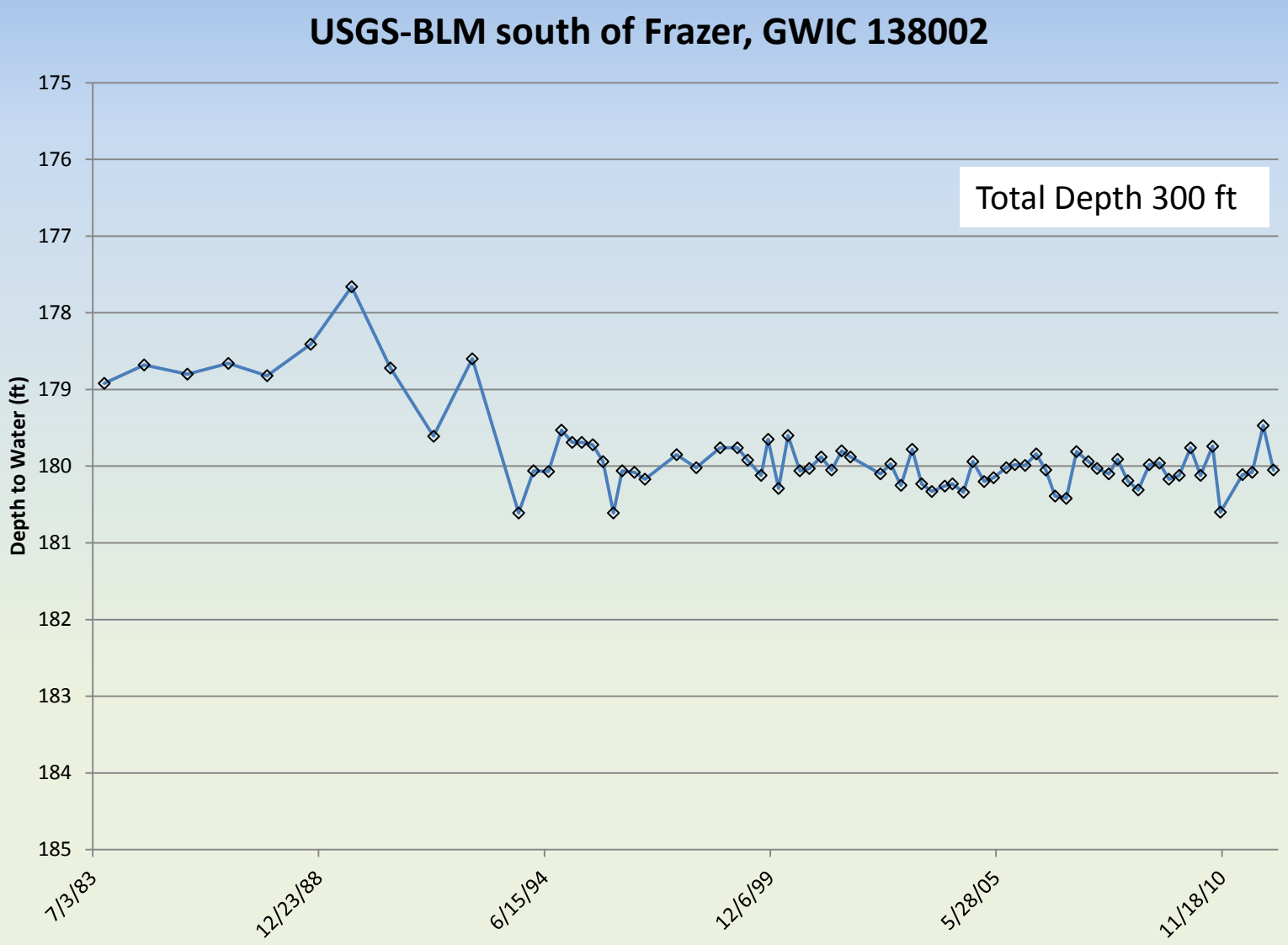
Gibson near Sand Springs, GWIC 27377

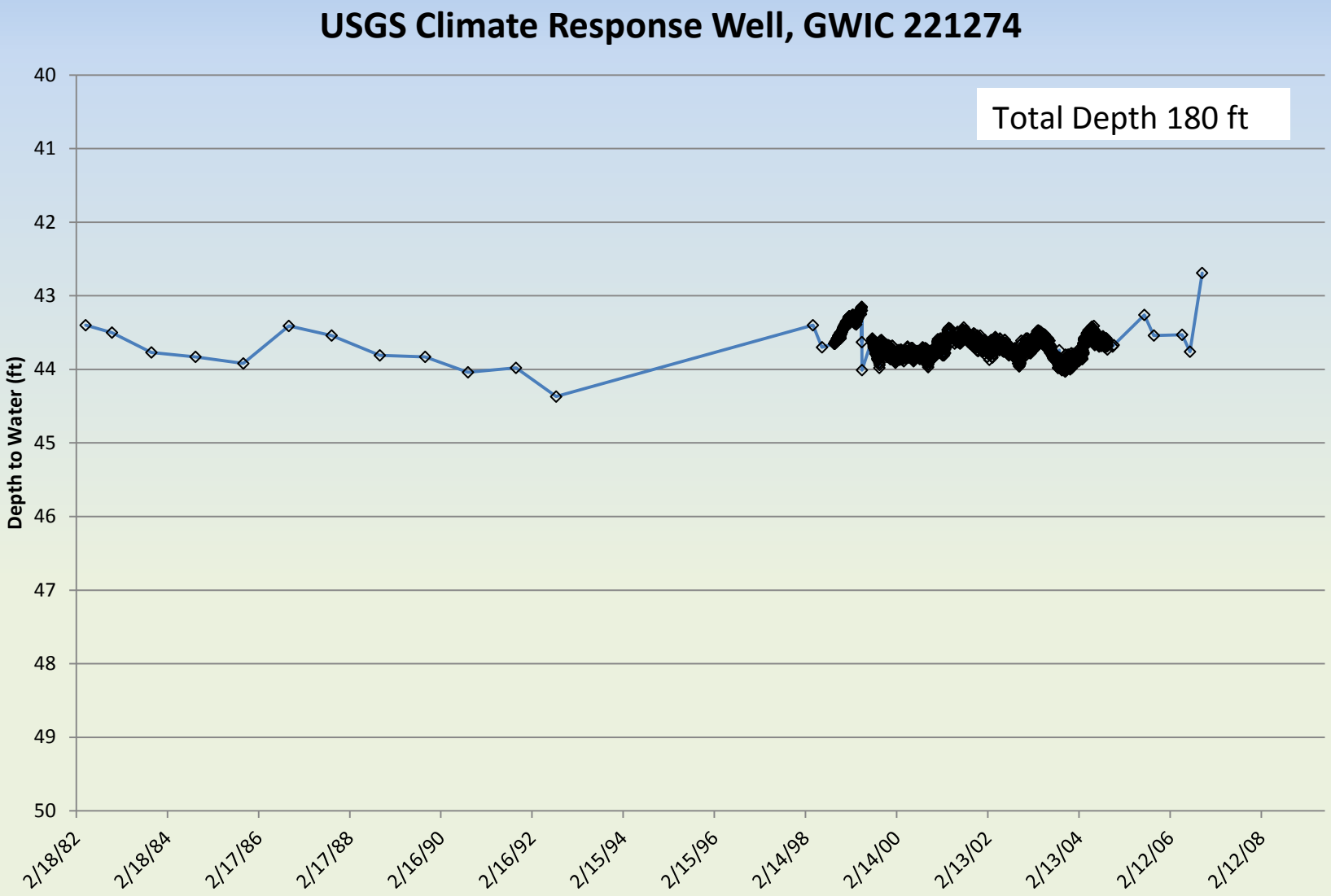


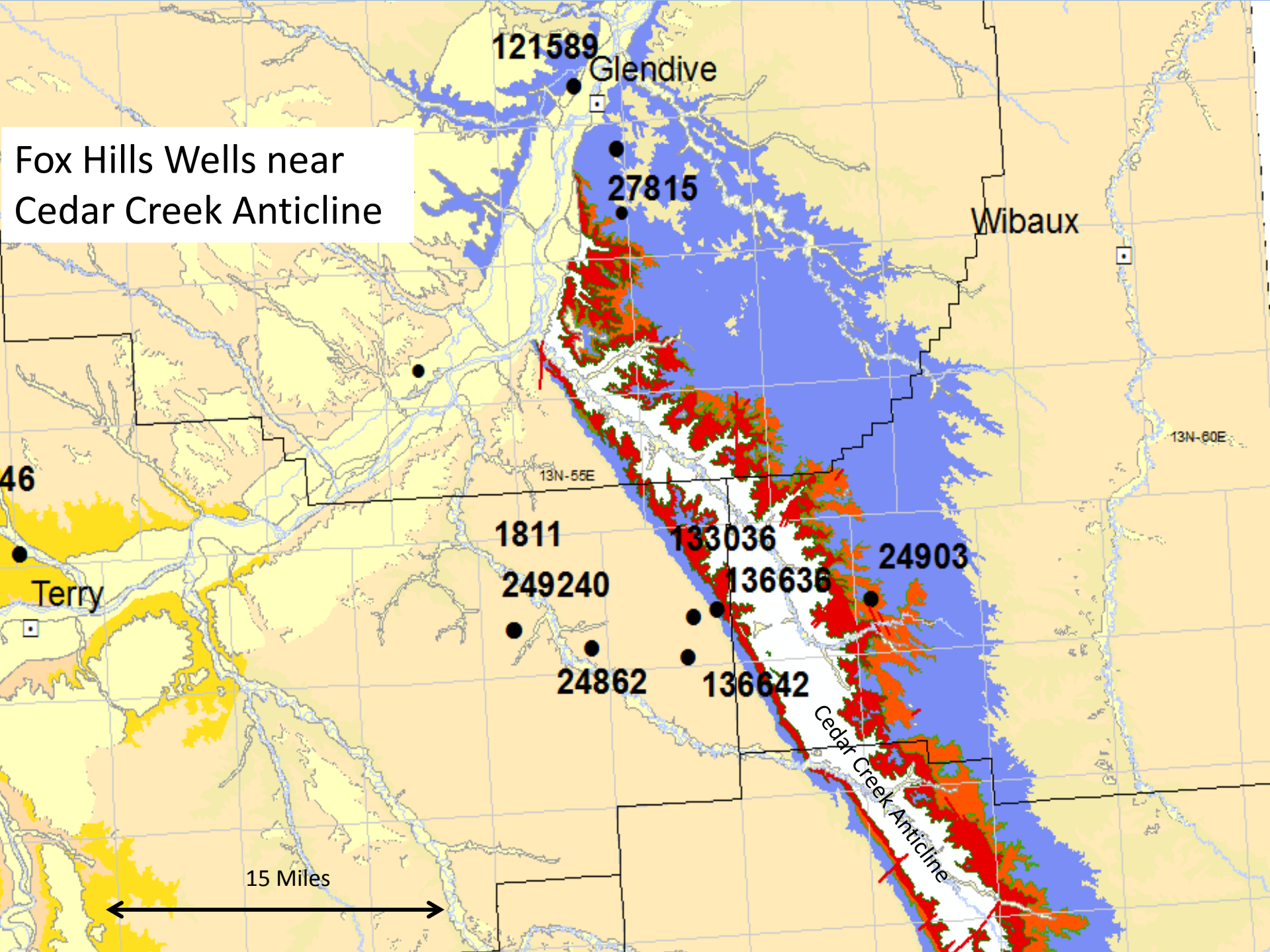

Hendricks near Ekalaka, GWIC 95030
Total Depth 360 ft
Depth to Water (ft)
90
95
100
105
110
115
120
125
130
12/6/99
4/19/01
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12

Olson Ranch BLM Well north of Jordan, GWIC 34908

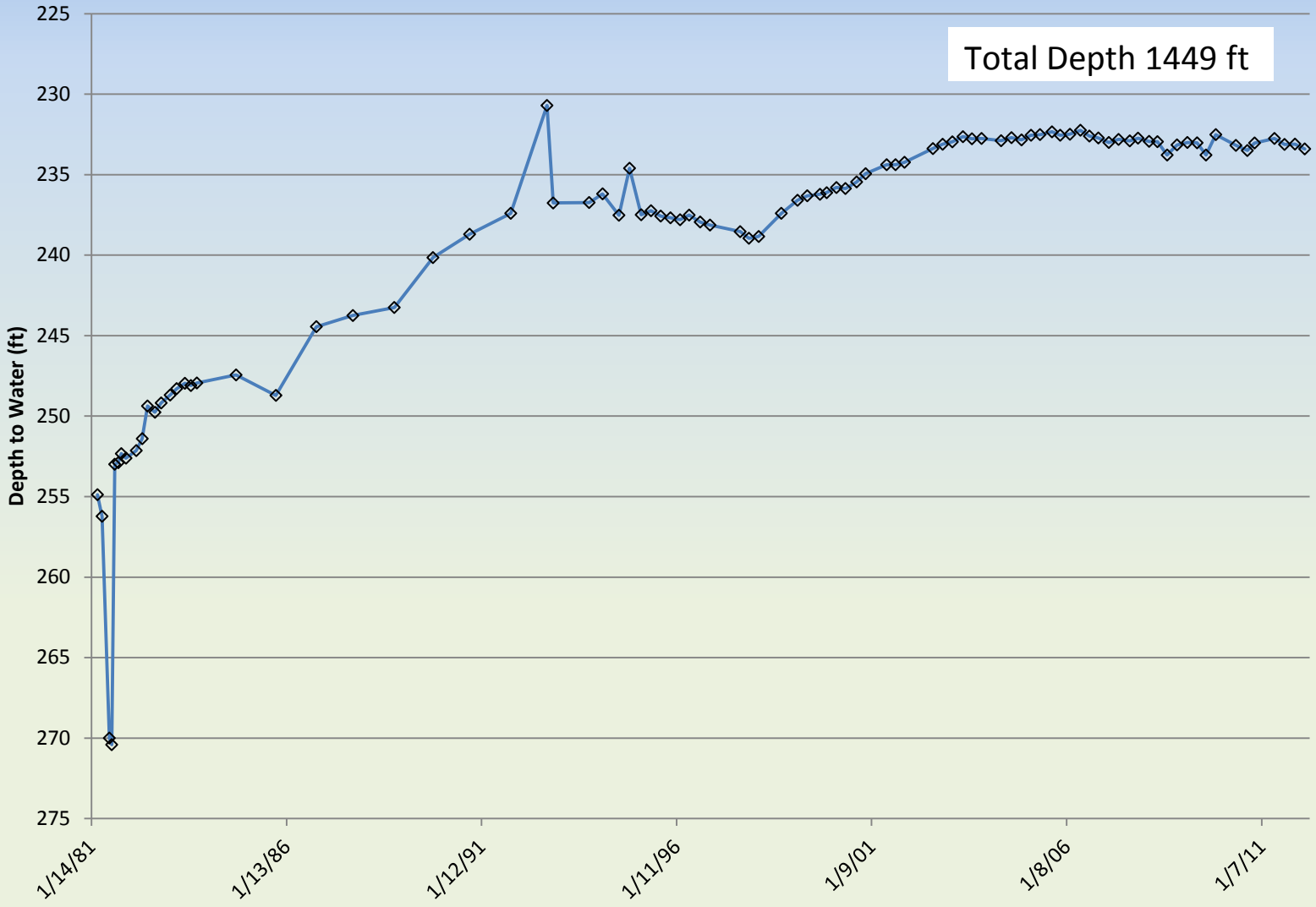



USGS-BLM south of Frazer, GWIC 138002
Total Depth 300 ft
Depth to Water (ft)
175
176
177
178
179
180
181
182
183
184
185
7/3/83
12/23/88
6/15/94
12/6/99
5/28/05
11/18/10

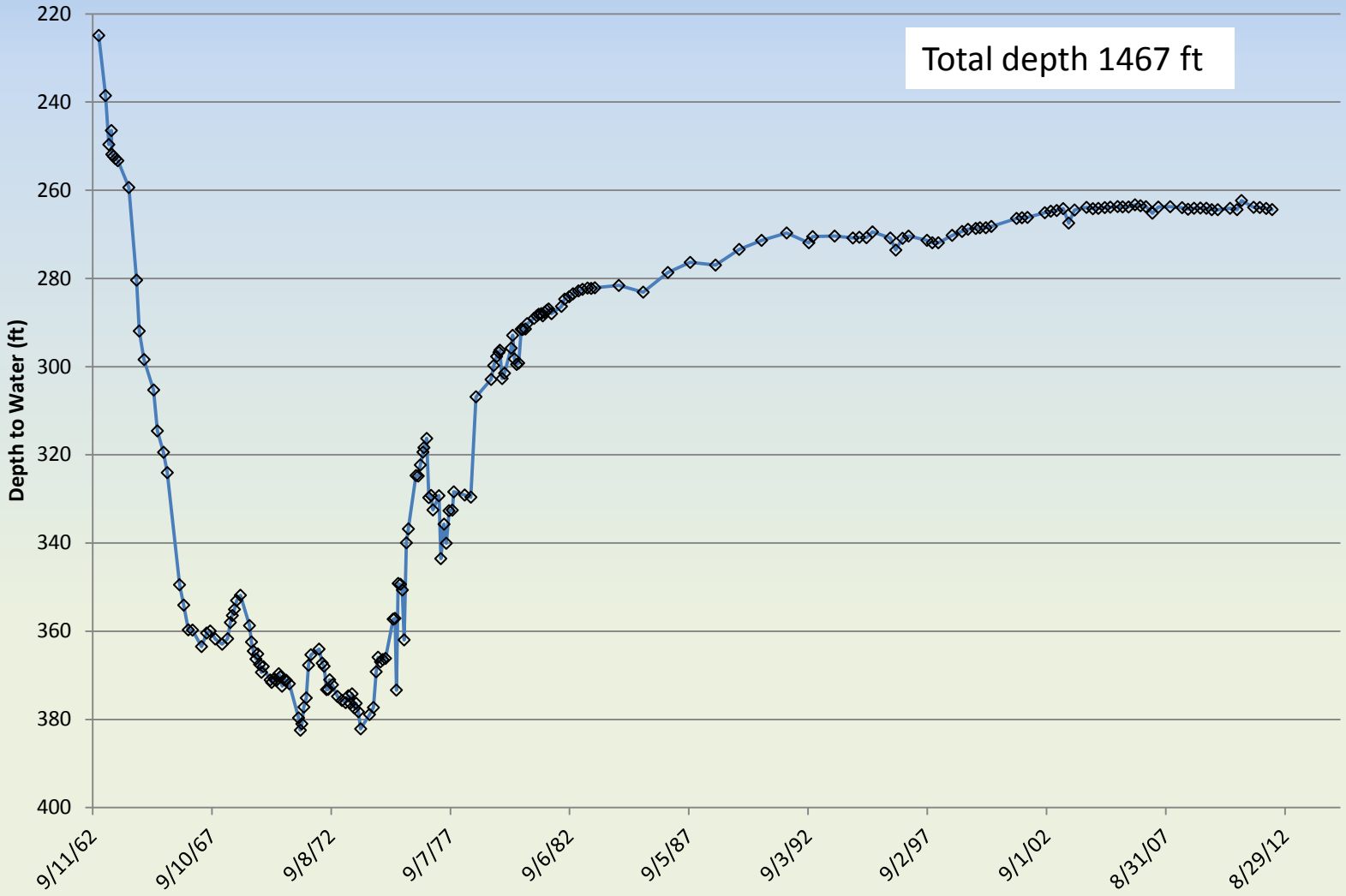

USGS Climate Response Well, GWIC 221274
Total Depth 180 ft
Depth to Water (ft)
40
41
42
43
44
45
46
47
48
49
50
2/18/82
2/18/84
2/17/86
2/17/88
2/16/90
2/16/92
2/15/94
2/15/96
2/14/98
2/14/00
2/13/02
2/13/04
2/12/06
2/12/08


Fox Hills Wells near
Cedar Creek Anticline
121589
Glendive
27815
Wibaux
13N-60E
13N-55E
46
Terry
1811
133036
24903
249240
136636
24862
136642
Cedar Creek Anticline
15 Miles

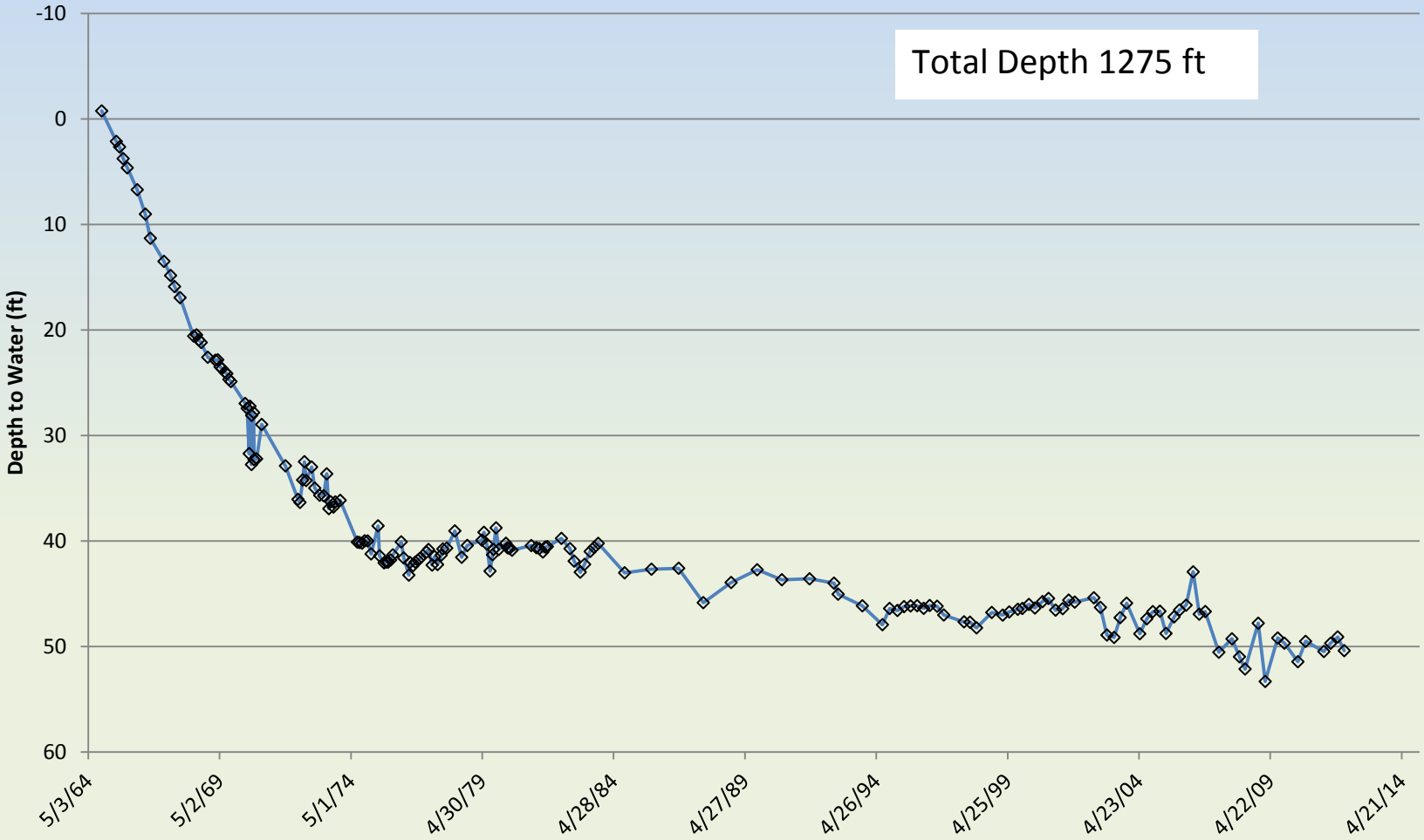
Shell Western Well 7, GWIC 133036



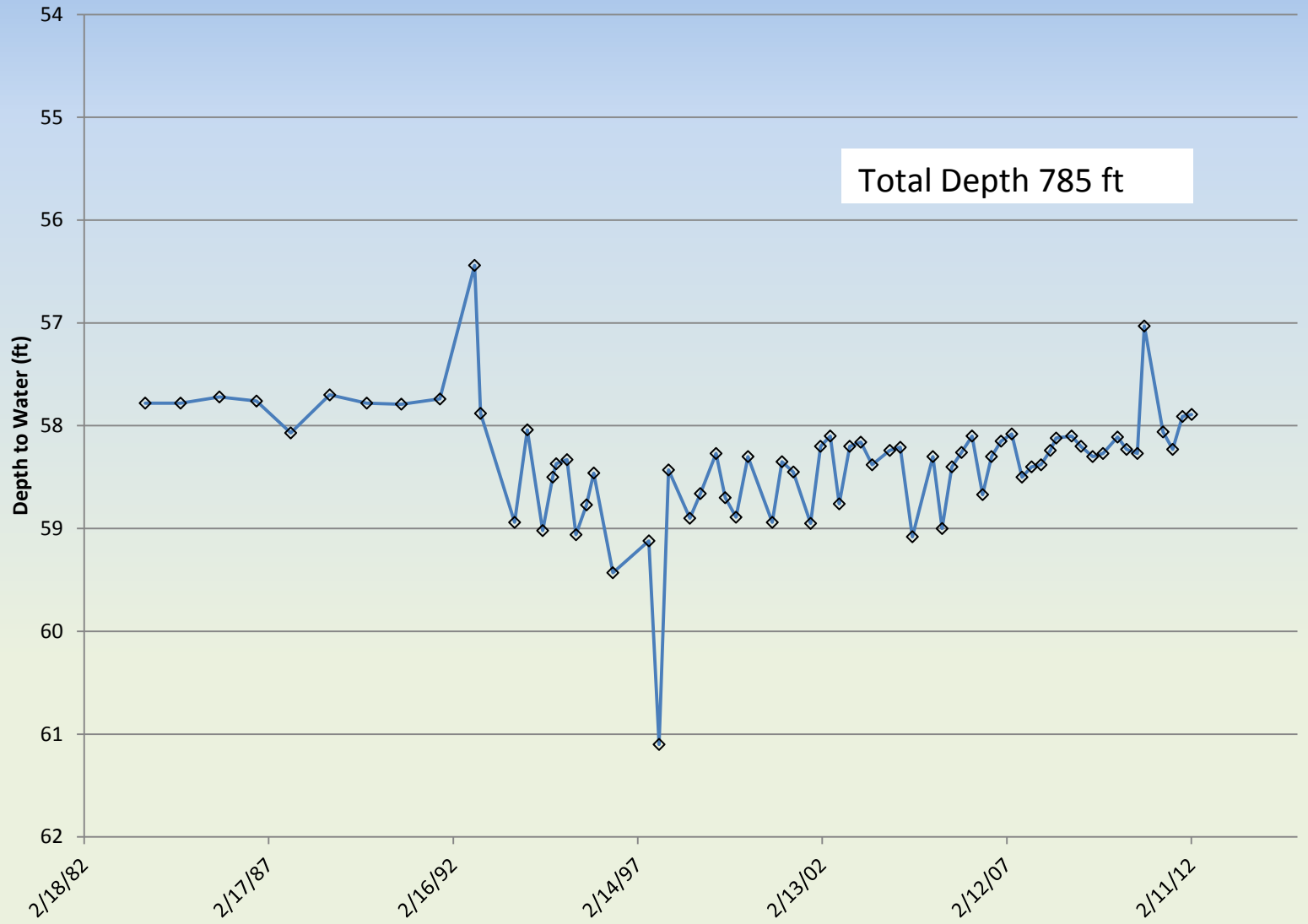
BLM Shell Oil Co., GWIC 136642



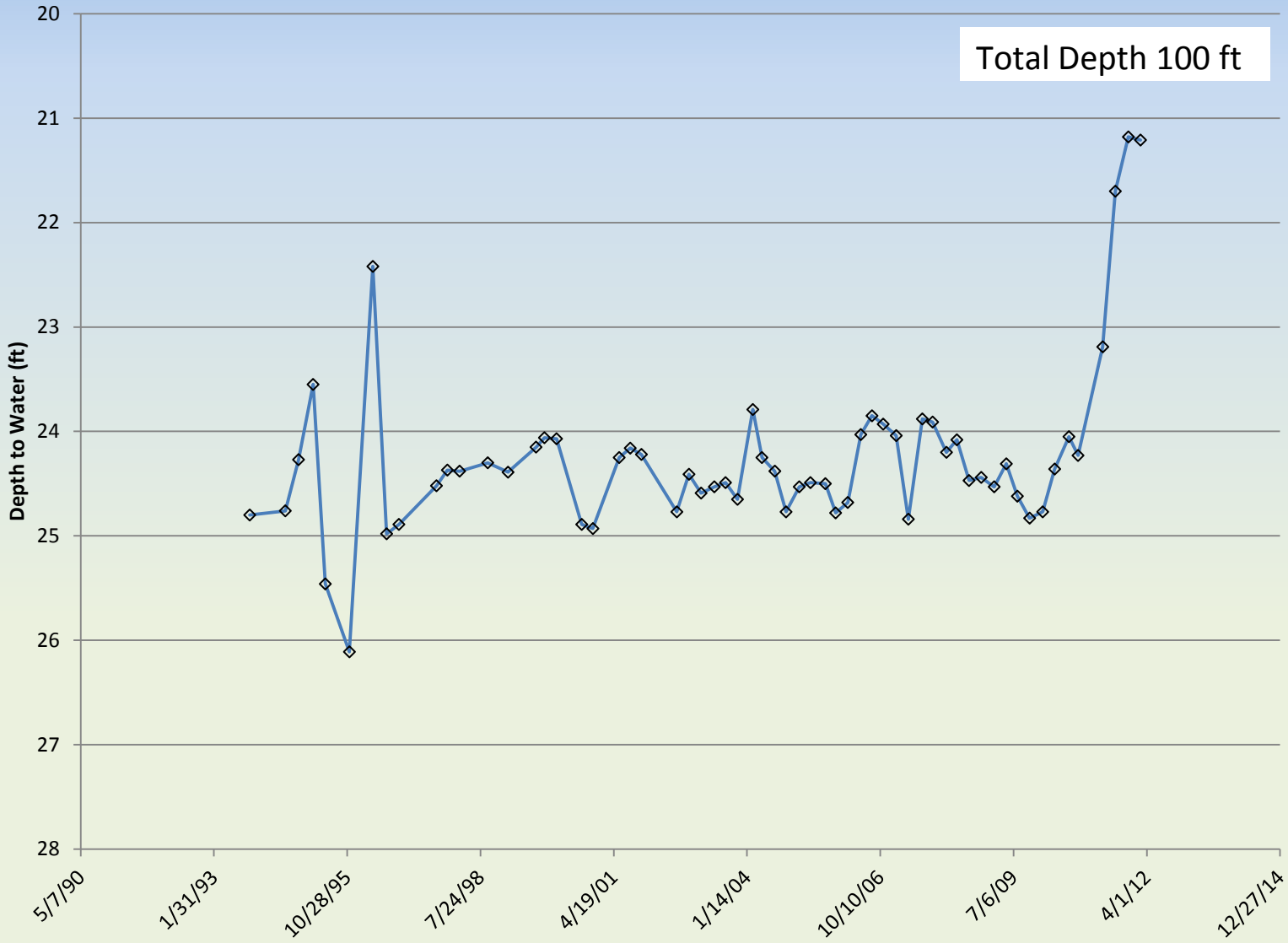
Thoeny, GWIC 24862



Makoshika State Park, GWIC 27815



Lost in Time Ranch, GWIC 24903



RECHARGE
Agriculture and Municipal
+ Oil Development
Fox Hills/Hell Creek
Water Balance

Questions ?